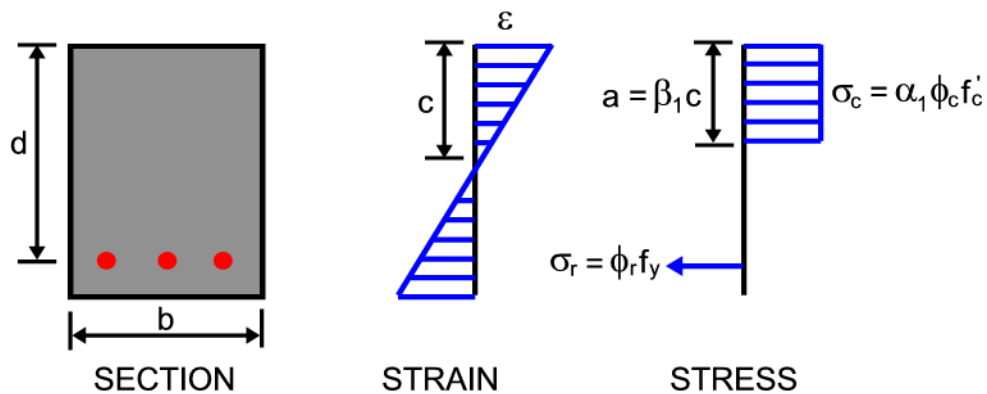


STRUCTWARE[®]
Program Documentation

for

CONSEC[®]

Concrete Section Analysis Program



CONTENTS

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Program information	
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STRUCTWARE

SHEET A-1 OF _____

JOB TITLE CONSEC Documentation ORIGINATOR RM DATE 9/17/2005

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

INTRODUCTION

CONSEC may be used to perform concrete section analysis of reinforced concrete members with or without embedded steel shapes. Options are available to calculate section properties, interaction diagram, slenderness effects and perform section analysis and/or moment-curvature analysis for given loads.

The online help file and graphical interface is shown in Section B. Verification problems are included in Section C. Additional information is contained in the following files installed in the program directory.

License.txt - The license agreement contains the terms and conditions for use of this program and documentation.

Readme.txt – The installation instructions, copyright and trademark notices and version history is contained in this file.

The following steps are recommended for users new to the program or specific features.

1. To learn how to use the program, view the Flash Demonstration Movie that is installed along with the program and read the "Instructions" section of the help file.
2. To apply this program to a specific problem, find a similar case in the Verification Problems section of this document. Run the program to see if you can reproduce the results. If your problem varies significantly from the Verification Problem, you should perform manual calculations for verification.

STRUCTWARE

SHEET B1-1 OF _____

JOB TITLE CONSEC Documentation ORIGINATOR RM DATE 9/17/2005

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

ONLINE HELP FILE

[Consec help](#)

GRAPHICAL INTERFACE

CONCRETE SECTION ANALYSIS

File Define Reset View Help

DESIGN CRITERIA

DESIGN CRITERIA: AASHTO (1996)

UNITS: ☒ English ☐ Metric

MATERIAL STRENGTH

f'_c = 4000 E_c = 3605000
 f_y = 60000 E_r = 2.9E+07
 f_s = 36000 E_s = 2.9E+07

STRESS BLOCK

α_1 = .85
 β_1 = .85
 ϵ = .003

STRENGTH REDUCTION FACTORS

Tension and flexure: .9
 Comp and flexure: .7
 Shear and torsion: .85

RESISTANCE FACTORS

Concrete: 1
 Reinforcing: 1
 Struct Steel: 1

No input file specified No output file specified

CONCRETE SECTION ANALYSIS
_ □ ×

File Define Reset View Help

STEEL SHAPE
LOADS
STRESS-STRAIN

DESIGN CRITERIA
CONCRETE
REINFORCING

RECTANGULAR SECTIONS

No of Sections:

SECTION NO 1

Ytop: Depth: Width:

Add Subtract

← →

CIRCULAR SECTIONS

No of Sections:

SECTION NO 1

Ycenter: Radius:

Add Subtract

← →

No input file specified
No output file specified

CONCRETE SECTION ANALYSIS
_ □ ×

File Define Reset View Help

STEEL SHAPE
DESIGN CRITERIA

LOADS
CONCRETE

STRESS-STRAIN
REINFORCING

REINFORCING LINES

No of Lines:

LINE NO 1

Ybeg:	Length:	Angle:
0	0	0
	Nbar:	Abar:
	0	0
←		→

REINFORCING ARCS

No of Arcs:

ARC NO 1

Ycenter:	Radius:	Abeg:
0	0	0
Atot:	Nbar:	Abar:
0	0	0
←		→

No input file specified

No output file specified

CONCRETE SECTION ANALYSIS
_ □ X

File Define Reset View Help

DESIGN CRITERIA

CONCRETE
LOADS

REINFORCING
STRESS-STRAIN

STEEL SHAPE

RECTANGULAR SHAPES

No of Shapes:

SHAPE NO 1

Ytop:

Depth:

Width:

←

→

PIPE SHAPES

No of Shapes:

SHAPE NO 1

Ycen:

Radius:

Thick:

←

→

No input file specified

No output file specified

CONCRETE SECTION ANALYSIS
_ □ X

File Define Reset View Help

DESIGN CRITERIA

CONCRETE

REINFORCING

STEEL SHAPE

LOADS

STRESS-STRAIN

No of loads:

LOAD CONDITION NO 1

Axial load:

Moment:

Shear:

Torsion:

←
→

SLENDERNESS OPTIONS

☐ No slenderness effects

☒ Moment magnification

☐ Slender wall design

☐ General P-delta analysis

Set Slenderness Parameters

No input file specified

No output file specified

CONCRETE SECTION ANALYSIS

File Define Reset View Help

DESIGN CRITERIA

CONCRETE

REINFORCING

STEEL SHAPE

LOADS

STRESS-STRAIN

☒ Perform Moment-Curvature Analysis

Set Member Properties

CONCRETE MATERIAL MODEL

☐ Linear

ec0: .002

fc0: 5200

Eci: 4110328

☐ Simple

ecu: 0

fcu: 0

☒ Mander

esp: .005

fcc: 0

Calc fcc

STEEL MATERIAL MODEL

☐ Bilinear

REINFORCING POINT NO 1

Strain: -0.06

Stress: -95000

↑

↓

☒ Park

STEEL POINT NO 1

Strain: -0.2

Stress: -57600

↑

↓

No input file specified

No output file specified

MEMBER PROPERTY ... [Min] [Max] [X]

File

MEMBER PROPERTIES

Length: Keff: leff factor:

BOUNDARY CONDITIONS

End i: End j:

Shear restraint: ☒ ☒

Moment restraint: ☐ ☐

SLENDerness PARAMETERS [Min] [Max] [X]

File

LOAD CONDITION NO 1

Initial deflection: Initial rotation:

End i: End j: End i: End j:

M1ns: M1s:

M2ns: M2s:

BetaD: BetaDs:

☐ Tloads

STRUCTWARE

SHEET B2-8 OF

JOB TITLE CONSEC Documentation ORIGINATOR RM DATE 9/17/2005

JOB No. CALCULATION No. REVIEWER DATE

The screenshot shows a software window titled "CONFINEMENT REINFORCING" with a standard Windows-style title bar (minimize, maximize, close buttons). The window contains several input fields and a button, organized into four main sections:

- File**: A menu bar at the top left.
- TYPE**: A section with five radio button options:
 - ☐ Neglect confinement
 - ☒ Spirals
 - ☐ Circular hoops
 - ☐ Cross ties
 - ☐ Cylindrical steel casing
- HOOPS OR SPIRALS**: A section with one input field:
 - Diameter:
- CROSS TIES**: A section with four input fields:
 - Tie spacing:
 - Core width:
 - Core height:
 - No of x-dir bars:
 - No of y-dir bars:
- CONFIGURATION**: A section with five input fields:
 - Bar diameter:
 - Long spacing:
 - Concrete cover:
 - Yield strength:
 - Ultimate strain:
- Calc confined stress and strain**: A button located at the bottom right of the window.

CONTROL PARAMETERS

File

MOMENT-CURVATURE

Integration limits:

emin: cmin: rcinc:

emax: ccinc:

einc: cinc: bsinc:

psinc:

Park model:

☐ Simple ☒ Complex

MOMENT-AXIAL INTERACTION

inc: binc: pinc:

Number of strain increments = 400

Define Calculation

File Define

OUTPUT

☒ Input data echo

☒ Section properties

☒ Interaction diagram

☒ Slenderness effects

☒ Section analysis

☒ Moment-curvature

Perform Calculations

VERIFICATION PROBLEMS

1. [Rectangular section](#)
 - A. Section properties
 - B. Interaction diagram
 - C. Braced frame slenderness per ACI 318
 - D. Section analysis per ACI 318
 - E. Moment-curvature analysis with simple concrete and reinforcing models

2. [Circular section](#)
 - A. Section properties
 - B. Interaction diagram
 - C. Braced frame slenderness per AASHTO/AREMA
 - D. Section analysis per AASHTO/AREMA
 - E. Moment-curvature analysis with simple concrete and reinforcing models

3. [Slender wall design](#)
 - A. Section properties
 - B. Interaction diagram
 - C. Slender wall design per ACI-318

4. [Rectangular section with circular void](#)
 - A. Section properties
 - B. Interaction diagram
 - C. Braced frame slenderness per OHBDC
 - D. Section analysis per OHBDC

5. [Tee section](#)
 - A. Section properties
 - B. Interaction diagram

6. [Rectangular section with embedded steel wide flange](#)
 - A. Section properties
 - B. Interaction diagram

STRUCTWARE

SHEET C-2 OF

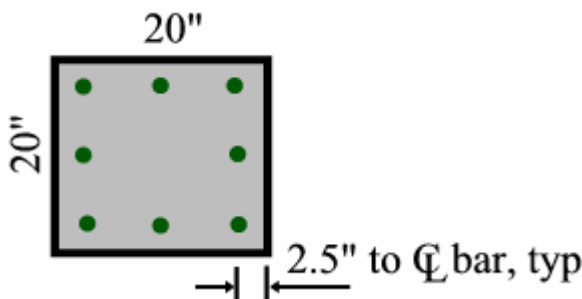
JOB TITLE CONSEC Documentation ORIGINATOR RM DATE 9/17/2005

JOB No. CALCULATION No. REVIEWER DATE

7. [Circular section encased in steel pipe](#)
 - A. Section properties
 - B. Interaction diagram
8. [Circular section with 2 rings of reinforcing](#)
 - A. Section properties
 - B. Interaction diagram
 - C. Moment-curvature analysis with complex concrete and reinf models
9. [ACI 318-02 verification](#)
 - A. Section properties (same as problem 1)
 - B. Interaction diagram (same as problem 1)
 - C. Section analysis per ACI 318-02 (new strength reduction factors)
10. [CAN/CSA-S6-00 verification](#)
 - A. Design criteria
 - B. Interaction diagram
 - C. Braced frame slenderness
11. [CSA-A23.3 verification](#)
 - A. Design criteria
 - B. Interaction diagram
 - C. Braced frame slenderness

VERIFICATION PROBLEM NO 1

Reference: PCA, "Notes on ACI 318-99" Example 13.1
File = VER1.OUT



$f'_c = 6000$ psi
 $f_y = 60$ ksi

(8) #10 bars
 $A_s = 1.27$ in² / bar

- Column A3 L = 256" k = 0.86

LOAD	M1 _{ns} (K-FT)	M2 _{ns} (K-FT)	P (KIPS)	β _d
1	82	162	1162	0.87
2	67	123	881	0.86

STRUCTWARE

SHEET C1-2 OF _____

JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

FILE = VER1.OUT

```
* * * * *
*
*           P R O G R A M   C O N S E C
*
*           INPUT DATA ECHO
*
* * * * *
12/09/01, 10:09 am
```

D E S I G N C R I T E R I A
=====

Design Criteria = ACI-318
Units = English (inches, pounds)

MATERIAL STRENGTH:

Concrete compressive strength	= 6000
Concrete modulus of elasticity	= 4415201
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9E+07

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 0.9
Compression and flexure	= 0.7
Shear and torsion	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.75
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 1
Reinforcing	= 1

C O N C R E T E C O N F I G U R A T I O N
=====

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	20	20	1

STRUCTWARE

SHEET C1-3 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

3 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
2.5	15	0	3	1.27
10	15	0	2	1.27
17.5	15	0	3	1.27

LOAD CONDITIONS

(Units = K-ft)

2 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	1162.0	0.0	0.0	0.0
2	881.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length	= 256
Effective length factor	= 0.86

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

SLENDERNESSES

(Moments in K-ft)

Moment magnification per design criteria

2 LOAD CONDITIONS:

No	M1ns	M2ns	M1s	M2s
1	82.0	162.0	0.0	0.0
2	67.0	123.0	0.0	0.0

No	BetaD	BetaDs	Tloads
1	0.87	0	0
2	0.86	0	0

No	di	dj	ri	rj
1	0	0	0	0
2	0	0	0	0

*
* PROGRAM CONSE C *
*
* OUTPUT DATA *
*

SECTION PROPERTIES
=====

GROSS CONCRETE SECTION:

Area = 4.0000E+02
Ybar = 1.0000E+01
Io = 1.3333E+04 About concrete CG

REINFORCING STEEL:

Area = 1.0160E+01
Ybar = 1.0000E+01
Io = 4.2863E+02 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 4.5657E+02
Ybar = 1.0000E+01
Inertia = 1.5720E+04

INTERACTION DIAGRAM
=====

Moments about centroid of gross concrete section
(Units = K-ft)

c	Mn	Pn	
	0.0	-609.6	Maximum tension
1.00	61.4	-533.1	
2.00	209.0	-310.9	
3.00	347.1	-96.3	
3.78	406.9	1.0	Pure bending
4.00	425.2	29.9	
5.00	493.3	147.8	
6.00	548.0	257.0	
7.00	593.0	405.9	
8.00	630.2	536.6	
9.00	653.7	644.5	
10.00	672.0	745.6	
10.36	677.4	781.0	Balanced strain
11.00	665.1	874.9	
12.00	646.4	1012.1	
13.00	627.2	1140.0	
14.00	606.5	1247.5	
14.10	604.3	1259.2	Load condition no 2
15.00	583.6	1362.2	
16.00	558.1	1472.0	
17.00	529.7	1578.0	

STRUCTWARE

SHEET C1-5 OF _____

JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

17.80	504.5	1660.4	Load condition no 1
18.00	497.9	1680.7	
19.00	462.6	1780.6	
	0.0	2078.2	Maximum compression

S L E N D E R N E S S E F F E C T S

=====

SLENDERNESS PER ACI-318:

LOAD CONDITION 1:

Pc = 2635.5

r = 5.774

kl/r = 38.1

kl/r limit = 27.9

Equivalent moment factor, Cm = 0.802

Non-sway magnification factor = 1.947

Sway magnification factor = 1.000

Magnified moment = 315.4

LOAD CONDITION 2:

Pc = 2649.7

r = 5.774

kl/r = 38.1

kl/r limit = 27.5

Equivalent moment factor, Cm = 0.818

Non-sway magnification factor = 1.469

Sway magnification factor = 1.000

Magnified moment = 180.7

S E C T I O N A N A L Y S I S

=====

(Units = K-ft)

LOAD CONDITION NO 1

For Axial load = 1162.3

Reduction factor = 0.700

Moment capacity = 353.2

Magnified moment = 315.4

LOAD CONDITION NO 2

For Axial load = 881.5

Reduction factor = 0.700

Moment capacity = 423.0

Magnified moment = 180.7

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C1-6 OF _____

TITLE _____

BY Rm DATE 2/15/2k

• Section properties

Concrete $A = (20)^2 = 400$

$$\bar{Y} = 10$$

$$I = 20(20)^3/12 = 13333$$

Reinf $A = 8 \times 1.27 = 10.16$

$$\bar{Y} = 10$$

$$I = 3 \times 1.27 (7.5)^2 (2) = 429$$

Trans $A = 400 + 10.16 \times \left(\frac{29000000}{4415201} - 1 \right) = 457$

$$\bar{Y} = 10$$

$$I = 13333 + 429 (5.57) = 15722$$

• Interaction diagram

a) Max tension $P_n = 10.16 \times 60 = 610 \text{ K}$

b) Pure bending

$$c = 3.78$$

$$a = 0.75 \times 3.78 = 2.84$$

$$f_1 = \frac{.003(17.5 - 3.78)(29 \times 10^6)}{3.78} = 315778 \quad \text{use } 60000$$

$$T_1 = 3.81 \times 60000 = 228600$$

$$f_2 = \frac{.003(10 - 3.78)(29 \times 10^6)}{3.78} = 143159 \quad \text{use } 60000$$

$$T_2 = 2.54 \times 60000 = 152400$$

$$f_3 = \frac{.003(2.5 - 3.78)(29 \times 10^6)}{3.78} = -29460 \text{ psi}$$

$$C_3 = 3.81 \times (-29460 + .85(60000)) = -92812 \text{ lbs}$$

$$C_c = 2.84 \times 20 \times .85 \times 60000 = -289680 \text{ lbs}$$

$$P_n = -1492 \text{ lbs}$$

$$M_n = 228600(17.5) + 152400(10) - 92812(2.5) - 289680(2.84/2) = 4881124 \text{ in-lbs} = 407 \text{ K'}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C1-7 OF _____

TITLE _____

BY Rm DATE 2/15/2K

c) Balanced stream

$$C = 10.36$$

$$a = 0.75 \times 10.36 = 7.77$$

$$\sigma_1 = 59959 \approx 60000 \quad (0.10)$$

$$T_1 = 3.81 \times 59959 = 228444$$

$$\sigma_2 = -3023 \text{ psi}$$

$$C_2 = 2.54(-3023) = -7679$$

$$\sigma_3 = -66006 \text{ use } -60000$$

$$C_3 = 3.81(-60000 + .85 \times 60000) = -209169$$

$$C_e = 7.77 \times 20 \times .85 \times 60000 = -792540$$

$$P_n = -781 \text{ k}$$

$$e = 10 - \left[\frac{228444(17.5) - 7679(10) - 209169(2.5) - 792540(7.77/2)}{-780944} \right]$$

$$e = 10.41$$

$$M_n = 780944(10.41)/12000 = 677 \text{ k'}$$

$$\begin{aligned} \text{d) Max } C &= [.85 \times 60000 \times 400 + 10.16(60000 - .85 \times 60000)] (.8)/1000 \\ &= 2078 \text{ k} \end{aligned}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C1-8 OF _____

TITLE _____

BY Rm DATE 2/16/00

• Slenderness effects

$$r = \sqrt{13333/400} = 5.77$$

$$KL/r = 0.86 \times 256 / 5.77 = 38.2$$

$$\text{Case 1: } KL/r_{\max} = 34 - 12 (984/1945.2) = 27.9$$

$$EI = \frac{(0.2 \times 4415201 \times 13333 + 29 \times 10^6 \times 429)}{(1 + .87)} = 1.295 \times 10^{10}$$

$$P_c = \frac{\pi^2 (1.295 \times 10^{10})}{(.86 \times 256)^2 (1000)} = 2637 \text{ k}$$

$$C_m = 0.6 + 0.4 (984/1945.2) = .802$$

$$S_{ns} = \frac{0.802}{1 - \frac{1162000}{.75 \times 2637000}} = 1.94$$

$$M_{\max} = 1.94 \times 1945200 / 12000 = 315 \text{ k'}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C1-9 OF _____

TITLE _____

BY Rm DATE 2/15/24

• I crack

$$a) \text{ Case 1 } \quad C = 17.80 \quad n-1 = 5.57$$

$$I_c = 20(17.8)^3/3 = 37598$$

$$I_r = 3.81 \times 5.57 (17.8 - 17.5)^2 \\ + 2.54 \times 5.57 (17.8 - 10)^2 \\ + 3.81 \times 5.57 (17.8 - 2.5)^2 = 5830$$

$$I_{cr} = 43428^{1.4}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C1-10 OF _____

TITLE _____

BY RM DATE 4/17/00

• Moment-curvature verification

File = VER1MC.OUT

Use simple concrete model and Park reinforcing model
with parabolic strain hardening. $\epsilon_{su} = 0.12$

Verify by comparison with COLX R (File = Ver1mcx.out)

$P = 100K$ (compression)

$\epsilon_{c\phi} = .002$ $f_{c\phi} = 7800 \text{ psi}$

$\epsilon_{cu} = .005$

$\epsilon_{su} = 0.12$ $f_{su} = 90000 \text{ psi}$

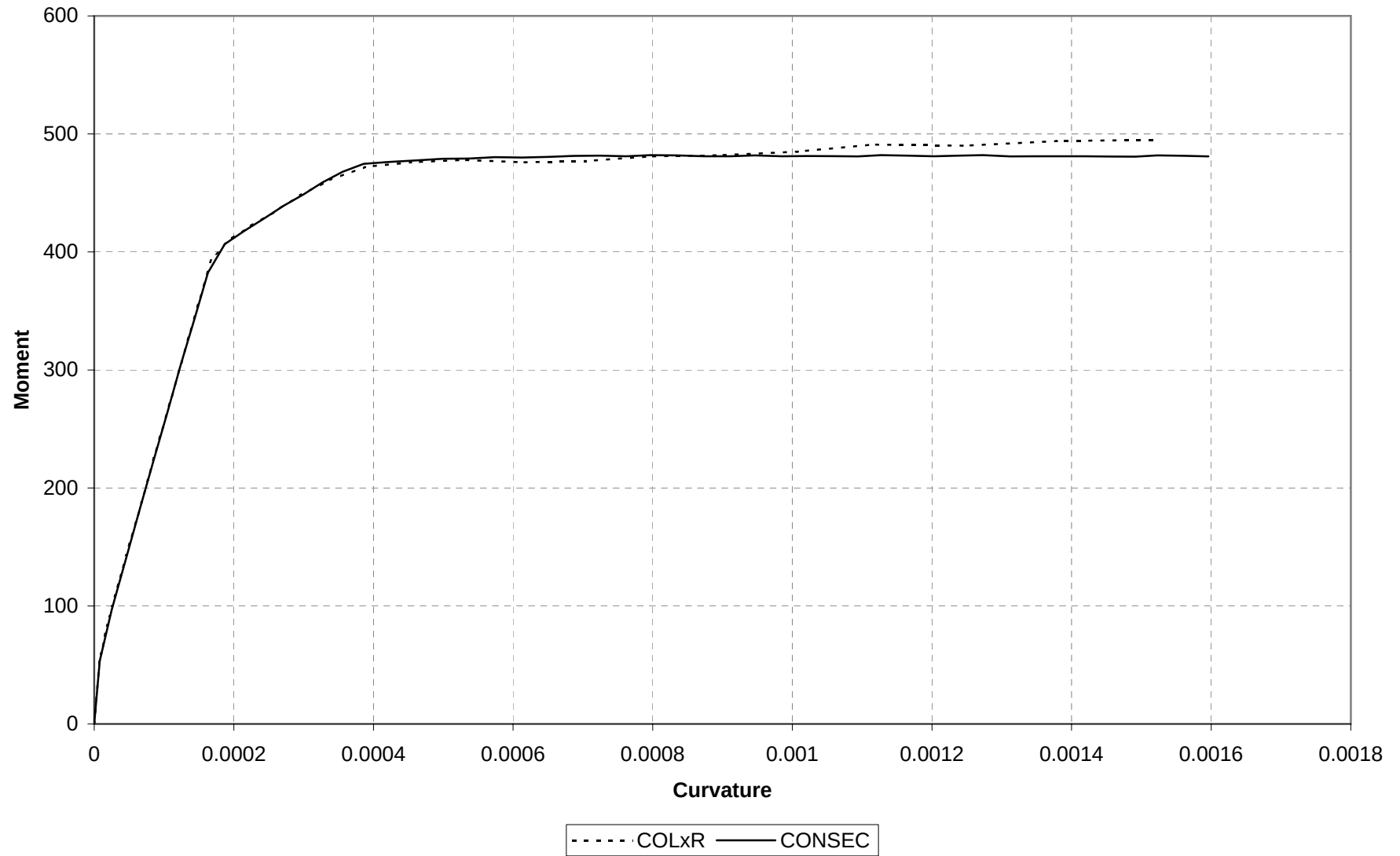
$\epsilon_{sh} = .01035$ $f_{sh} = 60000 \text{ psi}$

$\epsilon_{sy} = .00207$ $f_{sy} = 60000 \text{ psi}$

ITEM	CONSEC	COLX R	
1st yield ϵ	.001	.001	✓
c	5.35	5.2	✓
ϕ	.000187	.000193	✓
M	406.6	410	✓
Capacity ϵ	.005	.005	✓
c	3.13	3.28	✓
ϕ	.001596	.001524	✓
M	481.0	495	✓
I_{cr}	5185	4977	✓
M_{pl}	475.4	485	✓

∴ All values within 5%

20" Square Column Moment Curvature



STRUCTWARE

SHEET C1-12 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

FILE = VER1MC.OUT

```
* * * * *
*
*           P R O G R A M   C O N S E C
*
*           INPUT DATA ECHO
*
* * * * *
12/09/01, 10:13 am
```

S T R E S S - S T R A I N I N F O R M A T I O N

=====

CONCRETE MODEL:

Simple concrete model

```
Unconfined strain    = 0.002
Unconfined stress    = 7800
Modulus of elasticity = 5034104
Ultimate strain      = 0.005
Ultimate stress      = 0
Spalling strain      = 0.005
Confined stress      = 0
```

REINFORCING MODEL:

Park reinforcing model
(with parabolic strain hardening)

Point	Strain	Stress
1	-0.12	-90000
2	-0.01035	-60000
3	-0.00207	-60000
4	0.00207	60000
5	0.01035	60000
6	0.12	90000

C O N C R E T E C O N F I G U R A T I O N

=====

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	20	20	1

STRUCTWARE

SHEET C1-13 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

3 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
2.5	15	0	3	1.27
10	15	0	2	1.27
17.5	15	0	3	1.27

LOAD CONDITIONS

(Units = K-ft)

1 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	100.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length = 120

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	0	1
Moment restraint	0	1

```
* * * * *
*
*          P R O G R A M   C O N S E C
*
*          OUTPUT DATA
*
* * * * *
```

SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 4.0000E+02
Ybar = 1.0000E+01
Io = 1.3333E+04 About concrete CG

REINFORCING STEEL:

Area = 1.0160E+01
Ybar = 1.0000E+01
Io = 4.2863E+02 About reinf CG

STRUCTWARE

SHEET C1-14 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

TRANSFORMED CONCRETE SECTION:

Area = 4.5657E+02
Ybar = 1.0000E+01
Inertia = 1.5720E+04

M O M E N T C U R V A T U R E

=====

Moments about centroid of gross concrete section
(Units = K-ft)

Load Condition Number 1

Axial Load = 100.0

Strain	c	Axial	Curvature	Moment
0.00010	12.61	100.1	0.000008	53.3
0.00020	7.92	100.0	0.000025	96.7
0.00030	6.70	100.1	0.000045	139.0
0.00040	6.18	100.5	0.000065	181.4
0.00050	5.90	100.6	0.000085	223.2
0.00060	5.73	100.4	0.000105	264.3
0.00070	5.63	101.1	0.000124	304.6
0.00080	5.56	100.9	0.000144	344.0
0.00090	5.52	101.4	0.000163	382.5
0.00100	5.35	100.3	0.000187	406.6
0.00110	5.12	100.7	0.000215	417.8
0.00120	4.94	101.2	0.000243	428.7
0.00130	4.79	100.8	0.000271	438.9
0.00140	4.67	100.3	0.000300	448.8
0.00150	4.58	101.1	0.000328	458.9
0.00160	4.50	100.2	0.000356	468.0
0.00170	4.40	100.5	0.000386	474.7
0.00180	4.25	100.6	0.000424	476.3
0.00190	4.12	100.6	0.000461	477.5
0.00200	4.01	101.2	0.000499	478.8
0.00210	3.91	100.4	0.000537	479.2
0.00220	3.83	101.2	0.000574	480.2
0.00230	3.76	101.5	0.000612	480.8
0.00240	3.69	100.1	0.000650	480.4
0.00250	3.64	101.4	0.000687	481.4
0.00260	3.59	101.4	0.000724	481.5
0.00270	3.54	100.3	0.000763	481.0
0.00280	3.51	101.6	0.000798	481.9
0.00290	3.47	101.1	0.000836	481.6
0.00300	3.44	101.7	0.000872	482.0
0.00310	3.41	101.7	0.000909	482.0
0.00320	3.38	101.1	0.000947	481.7
0.00330	3.36	101.8	0.000982	482.2
0.00340	3.33	100.1	0.001021	481.1
0.00350	3.32	102.1	0.001054	482.3
0.00360	3.30	101.6	0.001091	482.0
0.00370	3.28	101.4	0.001128	481.8
0.00380	3.26	100.8	0.001166	481.4
0.00390	3.25	102.0	0.001200	482.1
0.00400	3.23	100.9	0.001238	481.4
0.00410	3.22	101.6	0.001273	481.8
0.00420	3.21	102.1	0.001308	482.1

Reinf tens yield

STRUCTWARE

SHEET C1-15 OF _____

JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

0.00430	3.19	100.2	0.001348	480.9
0.00440	3.18	100.3	0.001384	480.9
0.00450	3.17	100.2	0.001420	480.8
0.00460	3.17	102.4	0.001451	482.1
0.00470	3.16	102.0	0.001487	481.8
0.00480	3.15	101.5	0.001524	481.5
0.00490	3.14	100.8	0.001561	481.1
0.00500	3.13	100.0	0.001597	480.6

Yield curvature = 1.8691E-04
Ultimate curvature = 1.5974E-03
Idealized plastic moment = 475.6
Maximum tension = -383. At moment = 480.6

Cracked moment of inertia = 5.1849E+03
Based on 1st yield strain = -0.00227

LOCAL MEMBER DUCTILITY:

Idealized yield curvature = 2.1867E-04
Plastic hinge length = 22.9
Yield deflection = 1.050
Ultimate deflection = 4.476
Local member ductility = 4.3

STRUCTWARE

SHEET C1-16 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

FILE = VER1MCX.OUT

04-10-2000

***** COLDUCT (COLxR) *****

DUCTILITY of CIRCULAR, RECTANGULAR and OBLONG COLUMNS, Ver 7.02Rc, SEP-22-94

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JOB TITLE: Test. Circ., simple model, ver 7.02

RECTANGULAR Column Data

Column Width	(in.)	=	20.0
Column Depth	(in.)	=	20.0
Column Height	(ft.)	=	10.0 Cantilever
Plastic Hinge length	(in.)	=	21.0
Cover to lateral rebar	(in.)	=	1.365

Reinforcing Steel Data

Main bar		=	# 10
Number of bars		=	8
Yield stress	(ksi)	=	60.00
Ultimate stress	(ksi)	=	90.00
Young's Modulus	(ksi)	=	29000
Yield strain		=	.00207
Hardening strain		=	.01034
Ultimate strain		=	.12000

Confinement Steel Data

Spirals

Bar		=	# 4
Bar pitch/spacing	(in.)	=	12.000
Yield stress	(ksi)	=	60.00

Concrete Data, Unconfined or Confined with Rebar

Compressive strength (unconf.) (ksi)	=	7.800
Ultimate strain (unconfined)	=	.00500
Confinement Effectiveness Coeff. ke	=	0.000
Volumetric Steel Ratio (weak dir.)	=	.00000
Volumetric Steel Ratio (Strong dir.)	=	.00000
Volumetric Steel Ratio (Total)	=	.00000
Confining Pressure, Minimum (psi)	=	0.
Confining Pressure, Maximum (psi)	=	0.
Compressive strength (confined) (ksi)	=	0.000
Ultimate strain (confined)	=	.00500
Strength at ultimate strain (ksi)	=	3.900
Column axial load (kip)	=	100.0

STRUCTWARE

SHEET C1-17 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Rebar information

bar #	area	x	y
1	1.27	-7.50	7.50
2	1.27	0.00	7.50
3	1.27	7.50	7.50
4	1.27	-7.50	-7.50
5	1.27	0.00	-7.50
6	1.27	7.50	-7.50
7	1.27	7.50	0.00
8	1.27	-7.50	0.00

Concrete segment information

Seg. #	area	x	y
1	4.00	0.00	-9.90
2	4.00	0.00	-9.70
3	4.00	0.00	-9.50
4	4.00	0.00	-9.30
5	4.00	0.00	-9.10
6	4.00	0.00	-8.90
7	4.00	0.00	-8.70
8	4.00	0.00	-8.50
9	4.00	0.00	-8.30
10	4.00	0.00	-8.10
11	4.00	0.00	-7.90
12	4.00	0.00	-7.70
13	4.00	0.00	-7.50
14	4.00	0.00	-7.30
15	4.00	0.00	-7.10
16	4.00	0.00	-6.90
17	4.00	0.00	-6.70
18	4.00	0.00	-6.50
19	4.00	0.00	-6.30
20	4.00	0.00	-6.10
21	4.00	0.00	-5.90
22	4.00	0.00	-5.70
23	4.00	0.00	-5.50
24	4.00	0.00	-5.30
25	4.00	0.00	-5.10
26	4.00	0.00	-4.90
27	4.00	0.00	-4.70
28	4.00	0.00	-4.50
29	4.00	0.00	-4.30
30	4.00	0.00	-4.10
31	4.00	0.00	-3.90
32	4.00	0.00	-3.70
33	4.00	0.00	-3.50
34	4.00	0.00	-3.30
35	4.00	0.00	-3.10
36	4.00	0.00	-2.90
37	4.00	0.00	-2.70
38	4.00	0.00	-2.50
39	4.00	0.00	-2.30
40	4.00	0.00	-2.10
41	4.00	0.00	-1.90
42	4.00	0.00	-1.70

STRUCTWARE

SHEET C1-18 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

43	4.00	0.00	-1.50
44	4.00	0.00	-1.30
45	4.00	0.00	-1.10
46	4.00	0.00	-0.90
47	4.00	0.00	-0.70
48	4.00	0.00	-0.50
49	4.00	0.00	-0.30
50	4.00	0.00	-0.10
51	4.00	0.00	0.10
52	4.00	0.00	0.30
53	4.00	0.00	0.50
54	4.00	0.00	0.70
55	4.00	0.00	0.90
56	4.00	0.00	1.10
57	4.00	0.00	1.30
58	4.00	0.00	1.50
59	4.00	0.00	1.70
60	4.00	0.00	1.90
61	4.00	0.00	2.10
62	4.00	0.00	2.30
63	4.00	0.00	2.50
64	4.00	0.00	2.70
65	4.00	0.00	2.90
66	4.00	0.00	3.10
67	4.00	0.00	3.30
68	4.00	0.00	3.50
69	4.00	0.00	3.70
70	4.00	0.00	3.90
71	4.00	0.00	4.10
72	4.00	0.00	4.30
73	4.00	0.00	4.50
74	4.00	0.00	4.70
75	4.00	0.00	4.90
76	4.00	0.00	5.10
77	4.00	0.00	5.30
78	4.00	0.00	5.50
79	4.00	0.00	5.70
80	4.00	0.00	5.90
81	4.00	0.00	6.10
82	4.00	0.00	6.30
83	4.00	0.00	6.50
84	4.00	0.00	6.70
85	4.00	0.00	6.90
86	4.00	0.00	7.10
87	4.00	0.00	7.30
88	4.00	0.00	7.50
89	4.00	0.00	7.70
90	4.00	0.00	7.90
91	4.00	0.00	8.10
92	4.00	0.00	8.30
93	4.00	0.00	8.50
94	4.00	0.00	8.70
95	4.00	0.00	8.90
96	4.00	0.00	9.10
97	4.00	0.00	9.30
98	4.00	0.00	9.50
99	4.00	0.00	9.70
100	4.00	0.00	9.90

STRUCTWARE

SHEET C1-19 OF

JOB TITLE Verification Problem No. 1

ORIGINATOR RM

DATE 4/7/2004

JOB No. CALCULATION No.

REVIEWER

DATE

Force Equilibrium Condition of the x-section:

step	Max. Conc. Strain epscmax	Neutral Axis yna	Conc. Comp. Comp.	Steel comp. comp.	Total comp. comp.	Total tens. tens.	Curvature phi	Moment m(K-ft)
1	0.00010	-2.28	94.18	10.17	104.35	4.70	0.000008	55.
2	0.00011	-1.32	95.81	10.47	106.28	6.67	0.000010	60.
3	0.00012	-0.48	97.86	10.69	108.56	9.05	0.000012	65.
4	0.00014	0.24	100.54	11.10	111.64	12.08	0.000014	71.
5	0.00015	0.88	103.60	11.98	115.58	16.23	0.000016	77.
6	0.00017	1.40	107.72	12.94	120.66	20.86	0.000019	84.
7	0.00018	1.88	112.09	13.96	126.05	26.41	0.000022	91.
8	0.00020	2.28	117.42	15.08	132.50	32.64	0.000026	100.
9	0.00022	2.64	123.31	16.28	139.59	39.86	0.000030	109.
10	0.00025	2.96	129.87	17.57	147.44	48.13	0.000035	119.
11	0.00027	3.24	137.23	18.99	156.22	57.49	0.000040	130.
12	0.00030	3.44	146.49	20.61	167.10	67.19	0.000046	143.
13	0.00033	3.64	156.13	22.35	178.48	78.54	0.000052	156.
14	0.00037	3.84	166.14	24.19	190.32	91.85	0.000060	171.
15	0.00041	4.00	177.67	26.25	203.92	106.25	0.000068	188.
16	0.00045	4.12	190.97	28.60	219.57	121.55	0.000077	207.
17	0.00050	4.24	205.07	31.13	236.20	139.08	0.000086	227.
18	0.00055	4.32	221.39	34.04	255.43	157.35	0.000097	249.
19	0.00061	4.40	238.79	37.21	275.99	178.04	0.000109	273.
20	0.00067	4.48	257.05	40.65	297.71	201.47	0.000122	300.
21	0.00074	4.52	278.36	44.67	323.03	225.35	0.000136	329.
22	0.00082	4.56	300.98	49.08	350.06	252.08	0.000151	360.
23	0.00091	4.60	324.78	53.92	378.70	281.98	0.000168	394.

Start of tension steel yield

24	0.00100	4.80	339.24	57.63	396.87	296.90	0.000193	410.
25	0.00111	5.04	350.12	60.85	410.97	311.72	0.000224	422.
26	0.00123	5.24	362.56	64.40	426.96	328.15	0.000258	434.
27	0.00136	5.40	376.87	68.46	445.33	345.96	0.000295	448.
28	0.00150	5.56	389.70	72.44	462.14	367.00	0.000338	461.
29	0.00166	5.72	400.55	76.22	476.77	381.00	0.000388	472.
30	0.00183	5.96	401.29	77.23	478.53	381.00	0.000454	476.
31	0.00203	6.16	402.11	78.16	480.27	381.00	0.000528	478.
32	0.00224	6.36	397.78	77.55	475.33	381.00	0.000616	476.
33	0.00248	6.48	397.04	79.32	476.37	381.00	0.000704	477.
34	0.00274	6.56	397.26	82.70	479.96	382.77	0.000796	481.
35	0.00303	6.64	393.67	85.63	479.31	385.94	0.000901	482.
36	0.00335	6.68	391.17	91.35	482.53	389.09	0.001008	485.
37	0.00370	6.68	390.70	100.99	491.69	392.10	0.001115	491.
38	0.00409	6.72	382.52	107.49	490.02	395.89	0.001247	490.
39	0.00452	6.72	375.94	118.84	494.78	399.50	0.001379	494.
40	0.00500	6.72	366.34	131.38	497.72	403.40	0.001524	495.

Shear versus Deflection at top of column:

delta	V
0.04	5.47
0.05	5.97
0.06	6.50
0.07	7.07
0.08	7.69

STRUCTWARE

SHEET C1-20 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

0.09	8.37
0.11	9.12
0.13	9.95
0.15	10.87
0.17	11.88
0.19	13.01
0.22	14.26
0.25	15.64
0.29	17.15
0.33	18.82
0.37	20.66
0.41	22.68
0.47	24.90
0.52	27.33
0.58	29.97
0.65	32.86
0.73	36.00
0.81	39.40
0.93	41.01
1.00	42.17
1.08	43.42
1.16	44.80
1.26	46.08
1.37	47.21
1.53	47.55
1.70	47.84
1.90	47.65
2.10	47.75
2.32	48.06
2.56	48.16
2.80	48.46
3.05	49.07
3.35	49.04
3.66	49.35
3.99	49.54

Effective Moment of Inertia calculation

Mcr	(k-ft)	=	74
Multimate	(k-ft)	=	495
Igross	(ft^4)	=	0.64
Agross	(ft^2)	=	2.78

step	Ie(ft^4)	location from bot. of col.
1	0.64	8.9
2	0.64	8.8
3	0.64	8.7
4	0.64	8.6
5	0.62	8.4
6	0.55	8.3
7	0.48	8.2
8	0.43	8.0
9	0.38	7.8
10	0.35	7.6
11	0.32	7.4
12	0.30	7.1
13	0.28	6.8

STRUCTWARE

SHEET C1-21 OF _____JOB TITLE Verification Problem No. 1 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

14	0.27	6.5
15	0.26	6.2
16	0.25	5.8
17	0.24	5.4
18	0.24	5.0
19	0.24	4.5
20	0.23	3.9
21	0.23	3.4
22	0.23	2.7
23	0.23	2.0
24	0.23	1.7
25	0.23	1.5
26	0.23	1.2
27	0.23	1.0
28	0.24	0.7
29	0.24	0.5
30	0.24	0.4
31	0.25	0.3
32	0.25	0.4
33	0.25	0.4
34	0.25	0.3
35	0.26	0.3
36	0.26	0.2
37	0.26	0.1
38	0.26	0.1
39	0.26	0.0
40	0.26	0.0

Recommended value of 'Ie' based on initial slope
of moment-curvature diagram (ft⁴) = 0.24

SUMMARY OF RESULTS

Case	Defl. (in.)	P. Hinge Rot(rad)	Curvatures (rad/in)	Moment (ft-k)
Yield	0.93		0.000193	410
Nominal: see equilibrium table for values at desired conc. strain.				
Ultimate	4.08		0.001524	495
Idealized Yield	1.10		0.000229	485
Idealized Ultimate (Plastic Moment)	4.08	0.02725	0.001524	485

Displacement Ductilities:

Ideal. Ult. / Ideal. Yield = 3.72

Curvature Ductilities :

Ideal. Ult. / Ideal. Yield = 6.67

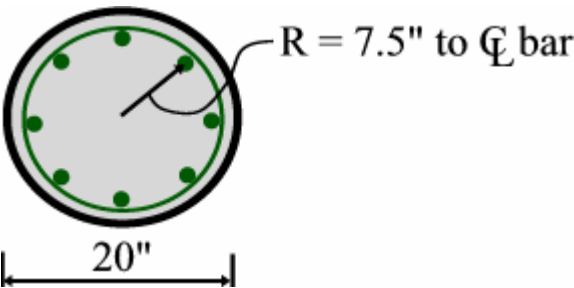
Maximum Strains :

Compression Conc. =	0.005000
Compression Steel =	0.001189
Tension Steel =	0.021677

end

VERIFICATION PROBLEM NO 2

File = VER2.OUT



$f'_c = 6000$ psi
 $f_y = 60$ ksi

(8) #10 bars
 $A_s = 1.27$ in² / bar

Column L = 192" k = 0.87

LOAD	M1 _{ns} (K-FT)	M2 _{ns} (K-FT)	P (KIPS)	β _d
1	82	82	1000	0.87

STRUCTWARE

SHEET C2-2 OF

JOB TITLE Verification Problem No. 2

ORIGINATOR RM

DATE 4/7/2004

JOB No. CALCULATION No.

REVIEWER

DATE

FILE = VER2.OUT

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* * * * *
*
*           P R O G R A M   C O N S E C
*
*           INPUT DATA ECHO
*
* * * * *
```

12/09/01, 2:16 pm

D E S I G N C R I T E R I A

Design Criteria = AASHTO

Units = English (inches, pounds)

MATERIAL STRENGTH:

Concrete compressive strength	= 6000
Concrete modulus of elasticity	= 4415201
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9E+07

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 0.9
Compression and flexure	= 0.75
Shear and torsion	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.75
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 1
Reinforcing	= 1

C O N C R E T E C O N F I G U R A T I O N

1 CIRCULAR SECTIONS:

Ycenter	Radius	Add
10	10	1

STRUCTWARE

SHEET C2-3 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

1 REINFORCING ARCS:

Ycenter	Radius	Abeg	Atot	Nbar	Abar
10	7.5	0	315	8	1.27

LOAD CONDITIONS

(Units = K-ft)

1 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	1000.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length	= 192
Effective length factor	= 0.87

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

SLENDERNESSES

(Moments in K-ft)

Moment magnification per design criteria

1 LOAD CONDITIONS:

No	M1ns	M2ns	M1s	M2s
1	82.0	82.0	0.0	0.0
No	BetaD	BetaDs	Tloads	
1	0.87	0	0	

STRUCTWARE

SHEET C2-4 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

No	di	dj	ri	rj
1	0	0	0	0

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* * * * *
*
*   P R O G R A M   C O N S E C
*
*   O U T P U T   D A T A
*
* * * * *
```

SECTION PROPERTIES

=====

GROSS CONCRETE SECTION:

Area = 3.1416E+02
Ybar = 1.0000E+01
Io = 7.8540E+03 About concrete CG

REINFORCING STEEL:

Area = 1.0160E+01
Ybar = 1.0000E+01
Io = 2.8575E+02 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 3.7073E+02
Ybar = 1.0000E+01
Inertia = 9.4451E+03

INTERACTION DIAGRAM

=====

Moments about centroid of gross concrete section
(Units = K-ft)

c	Mn	Pn	
	0.0	-609.6	Maximum tension
1.00	15.5	-590.1	
2.00	71.8	-506.4	
3.00	142.8	-388.5	
4.00	223.0	-233.8	
5.00	286.2	-110.9	
6.00	337.5	-0.1	
6.01	336.7	1.5	Pure bending
7.00	374.8	136.5	
8.00	411.1	268.2	
9.00	439.2	384.8	
10.00	446.3	529.4	

STRUCTWARE

SHEET C2-5 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

10.36	447.9	579.2	Balanced strain
11.00	443.2	675.3	
12.00	434.9	815.9	
13.00	424.5	947.1	
14.00	411.4	1057.7	
15.00	395.1	1174.7	
16.00	373.9	1282.1	
16.50	362.0	1333.7	Load condition no 1
17.00	349.3	1384.1	
18.00	321.5	1481.3	
19.00	290.9	1573.8	
	0.0	1836.0	Maximum compression

S L E N D E R N E S S E F F E C T S

SLENDERNESS PER AASHTO:

LOAD CONDITION 1:

$$P_c = 2879.4$$

$$r = 5.000$$

$$kl/r = 33.4$$

$$kl/r \text{ limit} = 22.0$$

$$\text{Equivalent moment factor, } C_m = 1.000$$

$$\text{Non-sway magnification factor} = 1.862$$

$$\text{Sway magnification factor} = 1.000$$

$$\text{Magnified moment} = 152.7$$

S E C T I O N A N A L Y S I S

(Units = K-ft)

LOAD CONDITION NO 1

$$\text{For Axial load} = 1000.3$$

$$\text{Reduction factor} = 0.750$$

$$\text{Moment capacity} = 271.5$$

$$\text{Magnified moment} = 152.7$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C2-C OF _____

TITLE _____

BY RM DATE 2/16/21

• Section properties

Concrete $I = \frac{\pi}{4} (10)^4 = 7854$

$$\bar{y} = 10$$

$$A = \pi (10)^2 = 314$$

Reinf

$$A = 10.16$$

$$\bar{y} = 10$$

$$I = [2(7.5)^2 + 4(7.5 \sin 45^\circ)^2] (1.27) = 286$$

Trans

$$n = 6.57$$

$$A = 314 + 10.16(5.57) = 371$$

$$\bar{y} = 10$$

$$I = 7854 + 286(5.57) = 9447$$

• Interaction diagram

a) Max tension $P_n = 10.16 \times 60 = 610^k$

b) Pure bending $C = 6.00$

$$a = 0.75 \times 6 = 4.5$$

$$\alpha = \cos^{-1}(5.5/10) = 56.633^\circ (.9884 \text{ rad})$$

$$A_c = (20)^2 \left[\frac{.9884 - 5 \sin 56.633 \cos 56.633}{4} \right]$$

$$A_c = 52.91$$

$$C_c = 52.91 \times .85 \times 6000 = 269837$$

$$\bar{y} = 10 - 7.34 = 2.66$$

From spreadsheet $\Sigma F_{rebu} = -269955$

$$P_n = 269837 - 269955 = -118$$

$$M_n = (269837 \times 2.66 - 4768532)/12000 = -338$$

↑ $\Sigma F_{Y \text{ rebu}}$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C2-7 OF _____

TITLE _____

BY Rm DATE 2/16/21

c) Balanced strain

$$C = 10.36$$

$$a = 7.77$$

$$\alpha = \cos^{-1}(2.23/10) = 77.115^\circ (1.346 \text{ rad})$$

$$A_c = (20)^2 \left[\frac{1.346 - \sin 77.115 \cos 77.115}{4} \right] = 112.85$$

$$C_c = 112.85 \times .85 \times 6000 = 575548$$

$$\bar{y} = 10 - \frac{(20)^3 \sin^3 77.115}{12 (112.85)} = 4.53$$

$$\left. \begin{array}{l} P_n = 579 \text{ K} \\ M_n = 448 \text{ K'} \end{array} \right\} \text{ From spreadsheet}$$

$$\begin{aligned} \text{d) Max compression } P_n &= .85 [.85 \times 6000 \times 314.16 + 10.16 (60000 - 5100)] / 1000 \\ &= 1836 \text{ K} \end{aligned}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C2-8 OF _____

TITLE _____

BY Rm DATE 2/16/2k

• Slenderness effects

$$r = (7854 / 314.16)^{1/2} = 5$$

$$KL/r = 0.87 \times 192 / 5 = 33.4$$

$$KL/r_{max} = 34 - 12 (984 / 984) = 22$$

$$EI = \frac{(0.2 \times 4415201 \times 7854 + 29 \times 10^6 \times 286)}{(1 + 0.87)} = 8144 \times 10^9$$

$$P_c = \frac{\pi^2 (8.144 \times 10^9)}{(0.87 \times 192)^2 (1000)} = 2881 \text{ K}$$

$$C_m = 0.6 + 0.4 (984 / 984) = 1.0$$

$$\delta_{hs} = \frac{1}{1 - \frac{1000}{0.75 \times 2881}} = 1.862$$

$$M_{mag} = 1.862 \times 984000 / 12000 = 153 \text{ K'}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C2-9 OF _____

TITLE _____

BY Rm DATE 4/17/00

• Moment - curvature verification

File = VER2MC.OUT

Use simple concrete model and Park reinforcing model
with parabolic strain hardening.

Verify by comparison with COLXR (Ver 2 mcx.out)

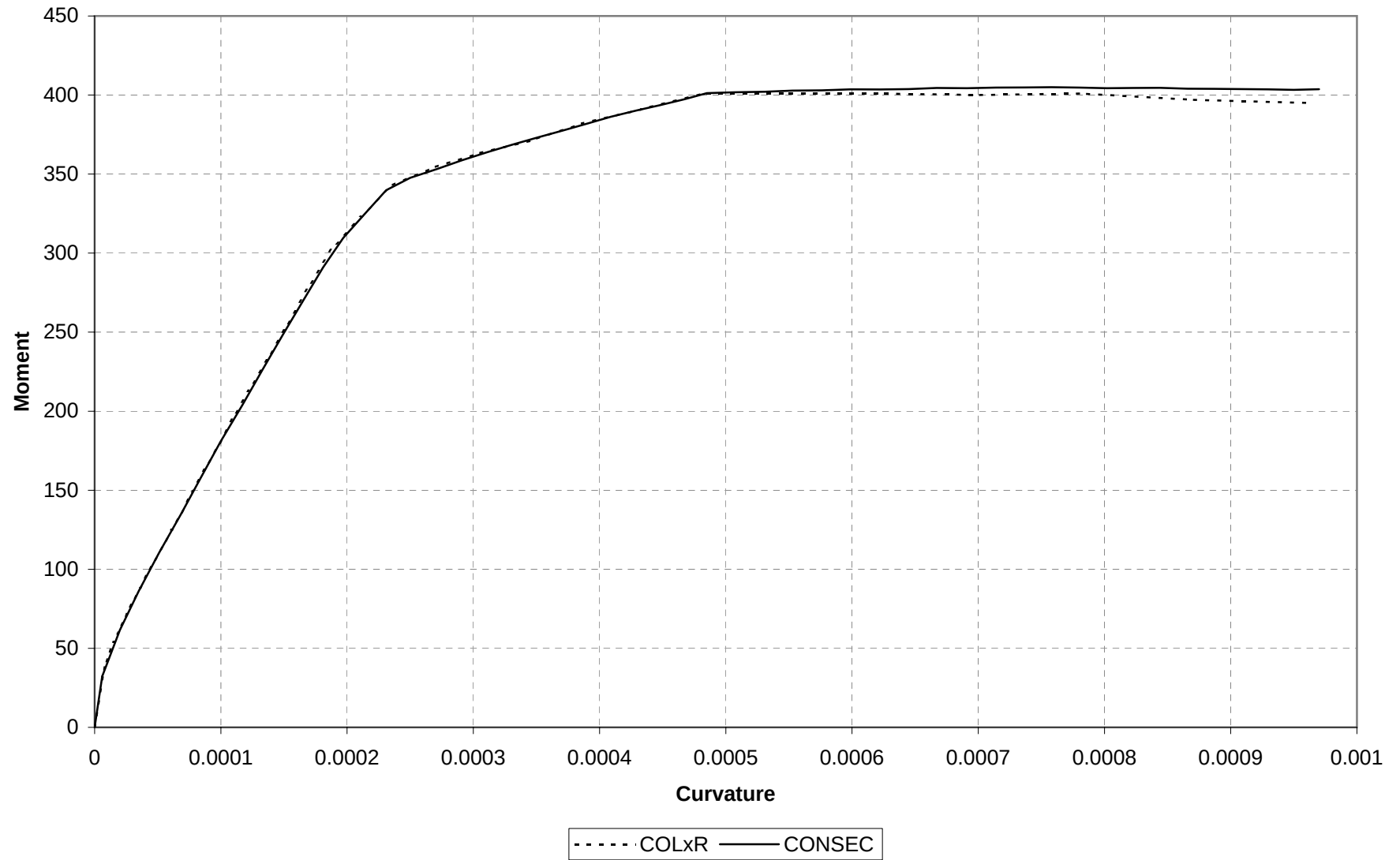
P = 100 K (compression)

Same stress-strain parameters as example 1

ITEM	CONSEC	COLXR	
1st T yield	E	.0013	.00136 ✓
	C	6.6	6.44 ✓
	ϕ	.000197	.000211 ✓
	M	309.6	323 ✓
1st C yield	E	.004	.00409 ✓
	C	5.27	5.24 ✓
	ϕ	.000758	.000781 ✓
	M	405.0	401 ✓
Failure	E	.005	.005 ✓
	C	5.16	5.2 ✓
	ϕ	.000970	.000962 ✓
	M	403.7	395 ✓
In		3747	3732 ✓
Mp		390.4	398 ✓

Items all within 5-7%

20" Circular Column Moment Curvature



STRUCTWARE

SHEET C2-11 OF _____

JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

FILE = VER2MC.OUT

```
* * * * *
*
*           P R O G R A M   C O N S E C
*
*           INPUT DATA ECHO
*
* * * * *
```

12/09/01, 2:20 pm

STRESS - STRAIN INFORMATION

=====

CONCRETE MODEL:

Simple concrete model

```
Unconfined strain    = 0.002
Unconfined stress    = 7800
Modulus of elasticity = 5034104
Ultimate strain      = 0.005
Ultimate stress      = 0
Spalling strain      = 0.005
Confined stress      = 0
```

REINFORCING MODEL:

Park reinforcing model
(with parabolic strain hardening)

Point	Strain	Stress
1	-0.12	-90000
2	-0.01035	-60000
3	-0.00207	-60000
4	0.00207	60000
5	0.01035	60000
6	0.12	90000

CONCRETE CONFIGURATION

=====

1 CIRCULAR SECTIONS:

Ycenter	Radius	Add
10	10	1

STRUCTWARE

SHEET C2-12 OF _____

JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

1 REINFORCING ARCS:

Ycenter	Radius	Abeg	Atot	Nbar	Abar
10	7.5	0	315	8	1.27

LOAD CONDITIONS

(Units = K-ft)

1 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	100.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length = 120

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	0	1
Moment restraint	0	1

```
*****
*
*          P R O G R A M   C O N S E C
*
*          OUTPUT DATA
*
*****
```

SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 3.1416E+02
Ybar = 1.0000E+01
Io = 7.8540E+03 About concrete CG

REINFORCING STEEL:

Area = 1.0160E+01
Ybar = 1.0000E+01
Io = 2.8575E+02 About reinf CG

STRUCTWARE

SHEET C2-13 OF _____JOB TITLE Verification Problem No. 2ORIGINATOR RMDATE 4/7/2004

JOB No. _____ CALCULATION No. _____

REVIEWER _____

DATE _____

TRANSFORMED CONCRETE SECTION:

Area = 3.7073E+02
Ybar = 1.0000E+01
Inertia = 9.4451E+03

M O M E N T C U R V A T U R E

=====

Moments about centroid of gross concrete section
(Units = K-ft)

Load Condition Number 1

Axial Load = 100.0

Strain	c	Axial	Curvature	Moment
0.00010	15.75	100.1	0.000006	32.3
0.00020	10.14	100.2	0.000020	61.6
0.00030	8.53	100.3	0.000035	86.3
0.00040	7.79	100.0	0.000051	110.4
0.00050	7.39	100.5	0.000068	134.3
0.00060	7.13	100.0	0.000084	157.8
0.00070	6.97	100.7	0.000100	181.1
0.00080	6.85	100.4	0.000117	203.9
0.00090	6.77	100.7	0.000133	226.3
0.00100	6.71	100.5	0.000149	248.3
0.00110	6.67	100.8	0.000165	269.8
0.00120	6.64	100.8	0.000181	290.9
0.00130	6.60	100.7	0.000197	309.6
0.00140	6.55	101.4	0.000214	325.0
0.00150	6.50	100.3	0.000231	339.8
0.00160	6.40	101.2	0.000250	348.0
0.00170	6.29	101.2	0.000270	353.5
0.00180	6.19	100.7	0.000291	358.6
0.00190	6.11	100.6	0.000311	363.7
0.00200	6.04	100.5	0.000331	368.6
0.00210	5.98	100.2	0.000351	373.2
0.00220	5.94	101.6	0.000370	378.1
0.00230	5.89	100.1	0.000390	381.8
0.00240	5.86	101.0	0.000410	386.2
0.00250	5.83	101.0	0.000429	390.1
0.00260	5.80	100.0	0.000448	393.5
0.00270	5.78	100.1	0.000467	397.2
0.00280	5.77	101.5	0.000485	401.1
0.00290	5.71	100.2	0.000508	401.6
0.00300	5.65	100.1	0.000531	402.0
0.00310	5.60	100.5	0.000554	402.6
0.00320	5.55	100.3	0.000577	402.9
0.00330	5.51	100.8	0.000599	403.4
0.00340	5.47	101.2	0.000622	403.9
0.00350	5.43	101.3	0.000645	404.2
0.00360	5.39	100.9	0.000668	404.3
0.00370	5.36	101.5	0.000690	404.8
0.00380	5.32	100.1	0.000714	404.4
0.00390	5.29	100.1	0.000737	404.6
0.00400	5.27	100.4	0.000759	404.7
0.00410	5.25	100.0	0.000781	404.4
0.00420	5.24	100.8	0.000802	404.7

Reinf tens yield

Reinf comp yield

STRUCTWARE

SHEET C2-14 OF _____

JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

0.00430	5.22	100.0	0.000824	404.2
0.00440	5.21	100.5	0.000845	404.3
0.00450	5.20	100.8	0.000865	404.3
0.00460	5.19	101.0	0.000886	404.2
0.00470	5.18	101.0	0.000907	404.0
0.00480	5.17	100.9	0.000928	403.8
0.00490	5.16	100.7	0.000950	403.6
0.00500	5.15	100.3	0.000971	403.3

Yield curvature = 1.9697E-04
Ultimate curvature = 9.7087E-04
Idealized plastic moment = 390.4
Maximum tension = -381. At moment = 403.3

Cracked moment of inertia = 3.7467E+03
Based on 1st yield strain = -0.00215

LOCAL MEMBER DUCTILITY:

Idealized yield curvature = 2.4840E-04
Plastic hinge length = 22.9
Yield deflection = 1.192
Ultimate deflection = 2.987
Local member ductility = 2.5

STRUCTWARE

SHEET C2-15 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

FILE = VER2MCX.OUT

04-07-2000

***** COLDUCT (COLXR) *****

DUCTILITY of CIRCULAR, RECTANGULAR and OBLONG COLUMNS, Ver 7.02Rc, SEP-22-94

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JOB TITLE: Test. Circ., simple model, ver 7.02

CIRCULAR		Column Data	
Column Diameter	(in.)	=	20.0
Column Height	(ft.)	=	10.0 Cantilever
Plastic Hinge length	(in.)	=	21.0
Cover to lateral rebar	(in.)	=	1.365

Reinforcing Steel Data

Main bar		=	# 10
Number of bars		=	8
Yield stress	(ksi)	=	60.00
Ultimate stress	(ksi)	=	90.00
Young's Modulus	(ksi)	=	29000
Yield strain		=	.00207
Hardening strain		=	.01034
Ultimate strain		=	.12000

Confinement Steel Data

Spirals		
Bar		= # 4
Bar pitch/spacing	(in.)	= 12.000
Yield stress	(ksi)	= 60.00

Concrete Data, Unconfined or Confined with Rebar

Compressive strength (unconf.) (ksi)	=	7.800
Ultimate strain (unconfined)	=	.00500
Confinement Effectiveness Coeff. ke	=	0.000
Volumetric Steel Ratio (weak dir.)	=	.00000
Volumetric Steel Ratio (Strong dir.)	=	.00000
Volumetric Steel Ratio (Total)	=	.00000
Confining Pressure, Minimum (psi)	=	0.

STRUCTWARE

SHEET C2-16 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Confining Pressure, Maximum (psi) = 0.
Compressive strength (confined) (ksi) = 0.000
Ultimate strain (confined) = .00500
Strength at ultimate strain (ksi) = 3.900

Column axial load (kip) = 100.0

Rebar information

bar #	area	x	y
1	1.27	0.00	7.50
2	1.27	5.30	5.31
3	1.27	7.50	0.01
4	1.27	5.31	-5.30
5	1.27	0.01	-7.50
6	1.27	-5.29	-5.31
7	1.27	-7.50	-0.02
8	1.27	-5.32	5.29

Concrete segment information

Seg. #	area	x	y
1	0.56	0.00	-9.90
2	0.97	0.00	-9.70
3	1.25	0.00	-9.50
4	1.47	0.00	-9.30
5	1.66	0.00	-9.10
6	1.82	0.00	-8.90
7	1.97	0.00	-8.70
8	2.11	0.00	-8.50
9	2.23	0.00	-8.30
10	2.35	0.00	-8.10
11	2.45	0.00	-7.90
12	2.55	0.00	-7.70
13	2.65	0.00	-7.50
14	2.73	0.00	-7.30
15	2.82	0.00	-7.10
16	2.90	0.00	-6.90
17	2.97	0.00	-6.70
18	3.04	0.00	-6.50
19	3.11	0.00	-6.30
20	3.17	0.00	-6.10
21	3.23	0.00	-5.90
22	3.29	0.00	-5.70
23	3.34	0.00	-5.50
24	3.39	0.00	-5.30
25	3.44	0.00	-5.10
26	3.49	0.00	-4.90
27	3.53	0.00	-4.70
28	3.57	0.00	-4.50
29	3.61	0.00	-4.30

STRUCTWARE

SHEET C2-17 OF _____

JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

30	3.65	0.00	-4.10
31	3.68	0.00	-3.90
32	3.72	0.00	-3.70
33	3.75	0.00	-3.50
34	3.78	0.00	-3.30
35	3.80	0.00	-3.10
36	3.83	0.00	-2.90
37	3.85	0.00	-2.70
38	3.87	0.00	-2.50
39	3.89	0.00	-2.30
40	3.91	0.00	-2.10
41	3.93	0.00	-1.90
42	3.94	0.00	-1.70
43	3.95	0.00	-1.50
44	3.97	0.00	-1.30
45	3.98	0.00	-1.10
46	3.98	0.00	-0.90
47	3.99	0.00	-0.70
48	3.99	0.00	-0.50
49	4.00	0.00	-0.30
50	4.00	0.00	-0.10
51	4.00	0.00	0.10
52	4.00	0.00	0.30
53	3.99	0.00	0.50
54	3.99	0.00	0.70
55	3.98	0.00	0.90
56	3.98	0.00	1.10
57	3.97	0.00	1.30
58	3.95	0.00	1.50
59	3.94	0.00	1.70
60	3.93	0.00	1.90
61	3.91	0.00	2.10
62	3.89	0.00	2.30
63	3.87	0.00	2.50
64	3.85	0.00	2.70
65	3.83	0.00	2.90
66	3.80	0.00	3.10
67	3.78	0.00	3.30
68	3.75	0.00	3.50
69	3.72	0.00	3.70
70	3.68	0.00	3.90
71	3.65	0.00	4.10
72	3.61	0.00	4.30
73	3.57	0.00	4.50
74	3.53	0.00	4.70
75	3.49	0.00	4.90
76	3.44	0.00	5.10
77	3.39	0.00	5.30
78	3.34	0.00	5.50
79	3.29	0.00	5.70
80	3.23	0.00	5.90

STRUCTWARE

SHEET C2-18 OF

JOB TITLE Verification Problem No. 2

ORIGINATOR RM

DATE 4/7/2004

JOB No.

CALCULATION No.

REVIEWER

DATE

81	3.17	0.00	6.10
82	3.11	0.00	6.30
83	3.04	0.00	6.50
84	2.97	0.00	6.70
85	2.90	0.00	6.90
86	2.82	0.00	7.10
87	2.73	0.00	7.30
88	2.65	0.00	7.50
89	2.55	0.00	7.70
90	2.45	0.00	7.90
91	2.35	0.00	8.10
92	2.23	0.00	8.30
93	2.11	0.00	8.50
94	1.97	0.00	8.70
95	1.82	0.00	8.90
96	1.66	0.00	9.10
97	1.47	0.00	9.30
98	1.25	0.00	9.50
99	0.97	0.00	9.70
100	0.56	0.00	9.90

Force Equilibrium Condition of the x-section:

	Max. Conc. Strain	Neutral Axis	Conc. Comp.	Steel comp.	Total comp.	Total tens.	Curvature phi	Moment m(K-ft)
step	epscmax	yna						
1	0.00010	-5.36	89.50	10.79	100.29	0.51	0.000007	34.
2	0.00011	-4.24	89.94	11.23	101.18	1.54	0.000008	38.
3	0.00012	-3.28	90.85	11.69	102.53	2.80	0.000009	41.
4	0.00014	-2.44	92.13	12.11	104.24	4.32	0.000011	45.
5	0.00015	-1.68	93.56	12.47	106.04	6.16	0.000013	50.
6	0.00017	-1.00	95.30	12.76	108.06	8.35	0.000015	54.
7	0.00018	-0.40	97.47	12.98	110.45	10.93	0.000018	59.
8	0.00020	0.12	100.24	13.34	113.58	14.09	0.000020	63.
9	0.00022	0.56	103.82	14.29	118.11	18.21	0.000024	69.
10	0.00025	1.00	107.14	15.23	122.37	23.34	0.000027	75.
11	0.00027	1.32	112.23	16.35	128.58	28.60	0.000031	81.
12	0.00030	1.64	117.29	17.49	134.79	34.96	0.000036	88.
13	0.00033	1.92	123.07	18.73	141.81	42.11	0.000041	96.
14	0.00037	2.16	129.78	20.10	149.88	50.06	0.000047	105.
15	0.00041	2.40	136.57	21.50	158.07	59.45	0.000054	114.
16	0.00045	2.56	145.57	23.21	168.78	68.92	0.000061	125.
17	0.00050	2.76	153.76	24.85	178.61	80.83	0.000069	136.
18	0.00055	2.88	164.64	26.91	191.55	92.57	0.000077	149.
19	0.00061	3.00	176.13	29.11	205.23	106.02	0.000087	163.
20	0.00067	3.12	188.04	31.44	219.48	121.41	0.000098	178.
21	0.00074	3.20	202.19	34.20	236.39	137.41	0.000109	195.
22	0.00082	3.28	216.95	37.18	254.14	155.51	0.000122	213.
23	0.00091	3.36	232.49	40.39	272.88	176.01	0.000137	233.
24	0.00100	3.40	250.76	44.25	295.01	196.88	0.000152	254.

STRUCTWARE

SHEET C2-19 OF _____

JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

25	0.00111	3.44	269.87	48.47	318.34	220.23	0.000169	278.
26	0.00123	3.48	289.70	53.08	342.77	246.35	0.000188	303.
Start of tension steel yield								
27	0.00136	3.56	307.58	57.55	365.12	269.18	0.000211	323.
28	0.00150	3.64	325.41	62.33	387.74	291.96	0.000236	343.
29	0.00166	3.80	336.83	65.96	402.79	303.60	0.000268	354.
30	0.00183	3.96	346.79	69.48	416.27	317.29	0.000304	363.
31	0.00203	4.12	354.81	72.81	427.62	333.38	0.000345	371.
32	0.00224	4.20	367.63	78.18	445.81	348.31	0.000386	382.
33	0.00248	4.28	377.33	83.81	461.15	365.35	0.000433	391.
34	0.00274	4.32	387.98	91.18	479.16	381.00	0.000482	401.
35	0.00303	4.48	383.85	94.02	477.87	381.00	0.000549	401.
36	0.00335	4.60	380.60	98.03	478.63	381.00	0.000620	401.
37	0.00370	4.72	373.77	101.55	475.32	381.00	0.000701	400.
Start of compression steel yield								
38	0.00409	4.76	372.69	107.08	479.77	381.00	0.000781	401.
39	0.00452	4.80	368.69	108.04	476.73	381.25	0.000870	397.
40	0.00500	4.80	365.75	111.40	477.15	382.02	0.000962	395.

Shear versus Deflection at top of column:

delta	V
0.03	3.36
0.04	3.75
0.04	4.14
0.05	4.55
0.06	4.96
0.07	5.39
0.08	5.85
0.10	6.35
0.11	6.89
0.13	7.48
0.15	8.13
0.17	8.84
0.20	9.63
0.23	10.49
0.26	11.44
0.29	12.50
0.33	13.63
0.37	14.91
0.42	16.30
0.47	17.82
0.52	19.49
0.59	21.30
0.66	23.27
0.73	25.43
0.81	27.76
0.90	30.26
1.01	32.31
1.07	34.33
1.14	35.36

STRUCTWARE

SHEET C2-20 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

1.23	36.30
1.32	37.12
1.42	38.21
1.52	39.10
1.64	40.06
1.79	40.07
1.95	40.13
2.14	39.97
2.32	40.08
2.53	39.75
2.74	39.55

Effective Moment of Inertia calculation

Mcr	(k-ft)	=	44
Multimate	(k-ft)	=	395
Igross	(ft^4)	=	0.38
Agross	(ft^2)	=	2.18

step	Ie(ft^4)	location from bot. of col.
1	0.38	9.2
2	0.38	9.1
3	0.38	9.0
4	0.38	8.9
5	0.38	8.7
6	0.36	8.6
7	0.33	8.5
8	0.30	8.4
9	0.27	8.3
10	0.24	8.1
11	0.23	7.9
12	0.21	7.8
13	0.20	7.6
14	0.19	7.3
15	0.18	7.1
16	0.17	6.8
17	0.17	6.6
18	0.17	6.2
19	0.16	5.9
20	0.16	5.5
21	0.16	5.1
22	0.16	4.6
23	0.16	4.1
24	0.16	3.6
25	0.16	3.0
26	0.16	2.3
27	0.16	1.8
28	0.16	1.3
29	0.16	1.1
30	0.16	0.8
31	0.16	0.6

STRUCTWARE

SHEET C2-21 OF _____JOB TITLE Verification Problem No. 2 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

32	0.16	0.3
33	0.16	0.1
34	0.16	0.0
35	0.16	0.0
36	0.16	0.0
37	0.16	0.0
38	0.16	0.0
39	0.16	0.0
40	0.16	0.0

Recommended value of 'Ie' based on initial slope
of moment-curvature diagram (ft⁴) = 0.18

SUMMARY OF RESULTS

Case	Defl. (in.)	P. Hinge Rot(rad)	Curvatures (rad/in)	Moment (ft-k)
Yield	1.01		0.000211	323
Nominal: see equilibrium table for values at desired conc. strain.				
Ultimate	2.86		0.000962	395
Idealized Yield	1.25		0.000260	398
Idealized Ultimate (Plastic Moment)	2.86	0.01476	0.000962	398

Displacement Ductilities:

Ideal. Ult. / Ideal. Yield = 2.30

Curvature Ductilities :

Ideal. Ult. / Ideal. Yield = 3.70

Maximum Strains :
Compression Conc. = 0.005000
Compression Steel = 0.002596
Tension Steel = 0.011827

End

STRUCTWARE

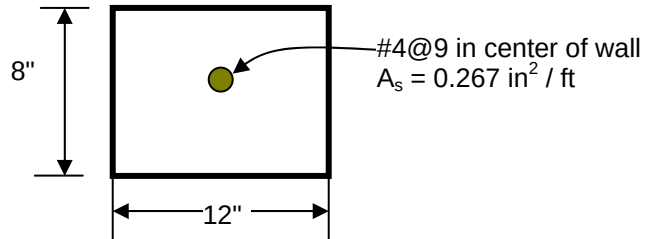
SHEET C3-1 OF _____

JOB TITLE Verification Problem No. 3 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

VERIFICATION PROBLEM NO 3

Reference: PCA, "Notes on ACI 318-99" Example 23.4
File = VER3.OUT



$f'_c = 4000 \text{ psi}$
 $f_y = 60 \text{ ksi}$

Wall H = 240"

LOAD	P (KIPS)	M (K-FT)
1	5.7	0.48
2	4.3	2.30

STRUCTWARE

SHEET C3-2 OF _____

JOB TITLE Verification Problem No. 3 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

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D E S I G N C R I T E R I A

Design Criteria = ACI-318
Units = English (inches, pounds)

MATERIAL STRENGTH:

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3605000
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9E+07

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 0.9
Compression and flexure	= 0.7
Shear and torsion	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.85
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 1
Reinforcing	= 1

C O N C R E T E C O N F I G U R A T I O N

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	8	12	1

STRUCTWARE

SHEET C3-3 OF _____JOB TITLE Verification Problem No. 3 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

1 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
4	1	0	1	0.267

LOAD CONDITIONS

(Units = K-ft)

2 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	5.7	0.5	0.0	0.0
2	4.3	2.3	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length	= 240
Effective length factor	= 1

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

SLENDERNESSES

(Moments in K-ft)

Slender wall design per ACI 318

STRUCTWARE

SHEET C3-4 OF _____JOB TITLE Verification Problem No. 3 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 9.6000E+01
Ybar = 4.0000E+00
Io = 5.1200E+02 About concrete CG

REINFORCING STEEL:

Area = 2.6700E-01
Ybar = 4.0000E+00
Io = 0.0000E+00 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 9.7881E+01
Ybar = 4.0000E+00
Inertia = 5.1200E+02

INTERACTION DIAGRAM

Moments about centroid of gross concrete section
(Units = K-ft)

C	Mn	Pn	
	0.0	-16.0	Maximum tension
0.38	4.2	-2.8	
0.47	5.1	0.3	Pure bending
0.61	6.6	5.1	Load condition no 2
0.66	7.1	6.9	Load condition no 1
0.76	8.1	10.3	
1.14	11.6	23.5	
1.52	14.7	36.7	
1.90	17.5	49.9	
2.28	20.0	63.1	
2.37	20.5	66.2	Balanced strain
2.66	22.1	80.5	
3.04	23.8	98.1	
3.42	25.2	114.7	
3.80	26.2	130.6	
4.18	26.9	146.0	

STRUCTWARE

SHEET C3-5 OF _____

JOB TITLE Verification Problem No. 3 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

4.56	27.2	161.0	
4.94	27.1	174.8	
5.32	26.7	189.4	
5.70	26.0	203.7	
6.08	24.9	217.9	
6.46	23.4	232.0	
6.84	21.6	246.0	
7.22	19.4	259.8	
	0.0	273.2	Maximum compression

S L E N D E R N E S S E F F E C T S

=====

SLENDER WALL DESIGN PER ACI-318

rho = 0.00556
rho_{max} = 0.01710
M_{cr} = 5.1

LOAD CONDITION 1:

P/A = 59.38
0.06 x f'_c = 240.00

Reduction factor = 0.870
Moment capacity = 6.2 From interaction diagram
Moment capacity = 5.9 From Ase formula
Magnified moment = 0.8

LOAD CONDITION 2:

P/A = 44.79
0.06 x f'_c = 240.00

Reduction factor = 0.878
Moment capacity = 5.8 From interaction diagram
Moment capacity = 5.6 From Ase formula
Magnified moment = 3.4

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C3-6 OF _____

TITLE _____

BY rem DATE 4/17/00

ACI 318 Chapter 14 formulas

$$I_n = n A_s e (d - c)^2 + \frac{l_c^3}{3}$$

$$A_s e = \frac{5700 + .267 \times 60000}{60000} = 0.362$$

$$a = \frac{0.362 \times 60000}{.85 \times 4000 \times 12} = 0.532 \quad c = \frac{.532}{.85} = .626$$

$$I_n = 8 (.362)(4 - .626)^2 + \frac{12 (.626)^3}{3} = 34.0$$

$$M_u = \frac{0.5 \times 12000}{1 - \frac{5(5700)(240)^2}{0.7 \times 48 \times 3605000 \times 34.0}} = 9977 \text{ in-lbs}$$

$$\Delta_u = \frac{5(9977)(240)^2}{0.7 \times 48 \times 3605000 \times 34.0} = 0.701$$

$$M_u = 6000 + 5700(.70) = 9977$$

$$= 0.83 \text{ K'}$$

$$\phi M_n = * 0.87 \times 0.362 \times 60000 \times (4 - .532/2) / 12000 = 5.9 \text{ K'}$$

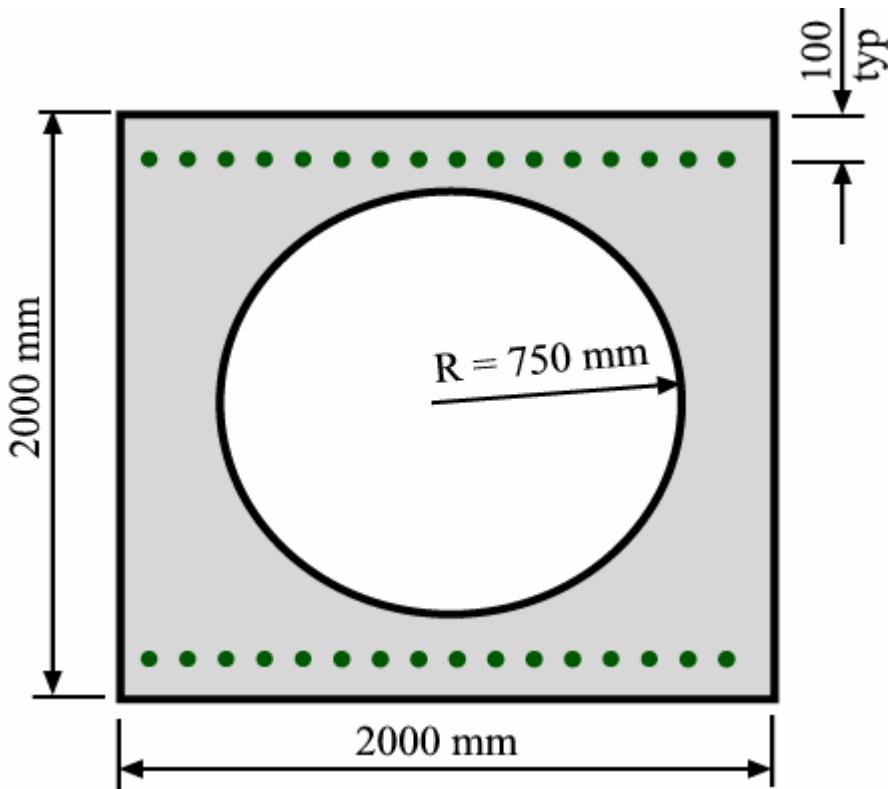
$$* .1 f'_c A_g = 38400$$

$$P_u = 5700$$

$$\phi = 0.9 - 0.2(5700/38400) = 0.87$$

VERIFICATION PROBLEM NO 4

File = VER4.OUT



$f'_c = 35\text{ MPa}$

$f_y = 400\text{ MPa}$

(16) 30M bars top and bottom

$A_s = 700\text{ mm}^2 / \text{bar}$

Member L = 30000 mm k = 1.0

LOAD	P (kN)	M (kN-m)
1	20000	10000

STRUCTWARE

SHEET C4-2 OF _____

JOB TITLE Verification Problem No. 4 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

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D E S I G N C R I T E R I A

Design Criteria = OHBDC
Units = Metric (millimeters, Newtons)

MATERIAL STRENGTH:

Concrete compressive strength	= 35
Concrete modulus of elasticity	= 29580
Reinforcing yield strength	= 400
Reinforcing modulus of elasticity	= 200000

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 1
Compression and flexure	= 1
Shear and torsion	= 1

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.81
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 0.75
Reinforcing	= 0.9

C O N C R E T E C O N F I G U R A T I O N

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	2000	2000	1

STRUCTWARE

SHEET C4-3 OF _____JOB TITLE Verification Problem No. 4 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

1 CIRCULAR SECTIONS:

Ycenter	Radius	Add
1000	750	-1

R E I N F O R C I N G C O N F I G U R A T I O N

2 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
100	1800	0	16	700
1900	1800	0	16	700

L O A D C O N D I T I O N S

(Units = kN-m)

1 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	20000.0	10000.0	0.0	0.0

M E M B E R P R O P E R T I E S

MEMBER PROPERTIES:

Member length	= 30000
Effective length factor	= 1

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

S L E N D E R N E S S

(Moments in kN-m)

Moment magnification per design criteria

1 LOAD CONDITIONS:

No	M1ns	M2ns	M1s	M2s
1	0.0	0.0	0.0	0.0

STRUCTWARE

SHEET C4-4 OF _____JOB TITLE Verification Problem No. 4ORIGINATOR RMDATE 4/7/2004

JOB No. _____

CALCULATION No. _____

REVIEWER _____

DATE _____

No	BetaD	BetaDs	Tloads
----	-------	--------	--------

1	0	0	1
---	---	---	---

No	di	dj	ri	rj
----	----	----	----	----

1	0	0	0	0
---	---	---	---	---

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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 2.2329E+06
Ybar = 1.0000E+03
Io = 1.0848E+12 About concrete CG

REINFORCING STEEL:

Area = 2.2400E+04
Ybar = 1.0000E+03
Io = 1.8144E+10 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 2.3619E+06
Ybar = 1.0000E+03
Inertia = 1.1894E+12

INTERACTION DIAGRAM

Moments about centroid of gross concrete section
(Units = kN-m)

C	Mn	Pn	
	0.0	-8064.0	Maximum tension
100.00	7097.0	-417.4	
105.00	7467.4	83.4	Pure bending
200.00	13071.6	6307.4	
300.00	16559.0	10594.0	
400.00	18639.0	13486.1	
500.00	20030.1	15670.0	
600.00	21026.8	17463.6	
700.00	21745.8	18978.7	

STRUCTWARE

SHEET C4-5 OF _____JOB TITLE Verification Problem No. 4 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

777.00	22156.9	20000.3	Load condition no 1
800.00	22259.9	20285.3	
900.00	22619.1	21435.6	
1000.00	22858.6	22472.0	
1100.00	23002.5	23431.5	
1188.00	23057.8	24243.6	Balanced strain
1200.00	22964.6	24459.8	
1300.00	22216.7	26183.6	
1400.00	21498.4	27811.3	
1500.00	20779.8	29398.8	
1600.00	20027.6	30998.2	
1700.00	19202.5	32661.3	
1800.00	18255.8	34443.4	
1900.00	17124.3	36409.0	
	0.0	43038.5	Maximum compression

S L E N D E R N E S S E F F E C T S

=====

SLENDERNESS PER OHBDC:

LOAD CONDITION 1:

Pc = 110174.3

r = 697.029

kl/r = 43.0

kl/r limit = 34.0

Equivalent moment factor, Cm = 1.000

Non-sway magnification factor = 1.319

Sway magnification factor = 1.000

Magnified moment = 13193.3

S E C T I O N A N A L Y S I S

=====

(Units = kN-m)

LOAD CONDITION NO 1

For Axial load = 20000.3

Reduction factor = 1.000

Moment capacity = 22156.9

Initial moment = 10000.0

Magnified moment = 13193.3

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET CA-6 OF _____

TITLE _____

BY Rm DATE 2/17/24

- Section properties

Concrete $A = (2000)^2 - \pi (750)^2 = 2232854$
 $\bar{y} = 1000$
 $I = \frac{(2000)^4}{12} - \frac{\pi (750)^4}{4} = 1.0848 \times 10^{12}$

Reinf $A = 32 \times 700 = 22400$
 $\bar{y} = 1000$
 $I = 700 [16 \times (900)^2 \times 2] = 1.8144 \times 10^{10}$

Trans $n = \frac{200000}{29580} = 6.76$
 $A = 2232900 + 22400(5.76) = 2361900$
 $\bar{y} = 1000$
 $I = 1.0848 \times 10^{12} + 1.8144 \times 10^{10}(5.76) = 1.1893 \times 10^{12}$

- Interaction diagram

a) Max tension $P_r = 22400 \times 0.9 \times \frac{400}{1000} = 8064 \text{ kN}$

b) Pure bending $C = 105$
 $a = 0.81 \times 105 = 85$
 $C_c = .75 \times .85 \times 35 \times 2000 \times 85 = 3793125$
 $\bar{y} = 42.5$
 $T = -400 \times .9 \times 700 \times 16 = -4032000$
 $\bar{y} = 1900$
 $S_b = \frac{(105 - 100)(.003)(200000)}{105} = 28.57$
 $C = 28.57 \times 700 \times 16 = 320000$
 $\bar{y} = 100$
 $P_r = 81 \text{ kN}$
 $M_r = 7468 \text{ kN-m}$

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JOB NO. _____

APPROVED _____ DATE _____

SHEET CA-7 OF _____

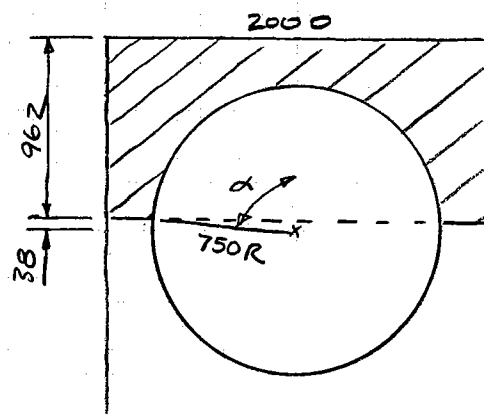
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BY Rm DATE 2/17/20

c) Balanced strain

$$c = 1188$$

$$a = 0.81 \times 1188 = 962$$



$$\alpha = 90 - \sin^{-1}\left(\frac{38}{750}\right)$$

$$\alpha = 87.096^\circ (1.52 R)$$

$$A_{c1} = (1500)^2 \left[\frac{1.52 - \sin 87.096 \cos 87.096}{4} \right] = 826539$$

$$\bar{y}_{c1} = 1000 - \frac{(1500)^3 \sin^3 87.096}{12(826539)} = 661$$

$$A_{c2} = 962 \times 2000 = 1924000$$

$$\bar{y}_{c2} = 962/2 = 481$$

$$\bar{y} = \frac{-826539 \times 661 + 1924000 \times 481}{1097461} = 345$$

$$A_c = 1097461$$

$$C_c = 1097461 \times .75 \times .85 \times 35 = 24487099$$

$$C = 700 \times 16 (.9 \times 400 - .75 \times .85 \times 35) = 3782100$$

$$\bar{y} = 100$$

$$T = -4032000$$

$$\bar{y} = 1900$$

$$P_r = 24237 \text{ kN}$$

$$e = 1000 - 48 = 952$$

$$M_r = 24237 \times 952 / 1000 = 23074 \text{ kN-m}$$

$$d) \text{ Max Compression } P_r = .75 \left[\frac{.75 \times .85 \times 35 \times 2232900 + 338 \times 22400}{1000} \right]$$

$$P_r = 43045 \text{ kN}$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET 04-8 OF _____

TITLE _____

BY Em DATE 2/17/00

- Slenderness effects

$$r = (1.0848 \times 10^{12} / 2.2329 \times 10^6)^{1/2} = 697$$

$$kl/r = (1)30000 / 697 = 43$$

$$kl/r (\max) = 34$$

$$EI = (.2 \times 1.0848 \times 10^{12} \times 29580 + 1.8144 \times 10^{10} \times 200000) = 1.0046 \times 10^{16}$$

$$P_c = \frac{\pi^2 (1.0046 \times 10^{16})}{(30000)^2 (1000)} = 110172 \text{ kN}$$

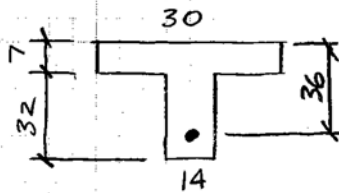
$$C_m = 1.0 \text{ for in-span loads}$$

$$\delta = \frac{1}{1 - \frac{20000}{.75 \times 110172}} = 1.319$$

$$M_{\max} = 10000 \times 1.319 = 13190 \text{ kN-m}$$

VERIFICATION PROBLEM NO 5

Ref. Wang & Salmon, "Reinforced Concrete Design"
 Example 9.4.2
 File = VER5.OUT



$$f'_c = 3000 \text{ psi}$$

$$f_y = 50000 \text{ psi}$$

$$n = \frac{29000000}{3122019} = 9.29$$

• Section properties

Concrete

$$A = 7 \times 30 + 14 \times 32 = 658$$

$$\bar{y} = \frac{210(3.5) + 448(23)}{658} = 16.78$$

$$I_o = \frac{30(7)^3}{12} + \frac{14(32)^3}{12} + 210(13.28)^2 + 448(6.22)^2 = 93455$$

Reinf

$$A = 12.48$$

$$\bar{y} = 36$$

Trans

$$A = 658 + 12.48(9.29) = 761$$

$$\bar{y} = \frac{658(16.78) + 12.48(9.29)(36)}{761} = 19.40$$

$$93455 + 658(2.62)^2 = 97972$$

$$12.48(36 - 19.4)^2 = 3439$$

$$I = 97972 + 9.29(3439) = 126481$$

• Interaction diagram

Textbook solution:

$$M_n = 1656 \text{ k'}$$

$$a = 9.48$$

$$c = 9.48 / 0.85 = 11.15$$

STRUCTWARE

SHEET C5-2 OF _____

JOB TITLE Verification Problem No. 5 ORIGINATOR RM DATE 4/7/2004

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D E S I G N C R I T E R I A

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Design Criteria = ACI-318
Units = English (inches, pounds)

MATERIAL STRENGTH:

Concrete compressive strength	= 3000
Concrete modulus of elasticity	= 3122019
Reinforcing yield strength	= 50000
Reinforcing modulus of elasticity	= 2.9E+07

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 0.9
Compression and flexure	= 0.7
Shear and torsion	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.85
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 1
Reinforcing	= 1

C O N C R E T E C O N F I G U R A T I O N

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2 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	7	30	1
7	32	14	1

STRUCTWARE

SHEET C5-3 OF _____JOB TITLE Verification Problem No. 5 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

1 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
36	1	0	1	12.48

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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 6.5800E+02
Ybar = 1.6777E+01
Io = 9.3454E+04 About concrete CG
Inertia = 9.7942E+04 About composite CG

REINFORCING STEEL:

Area = 1.2480E+01
Ybar = 3.6000E+01
Io = 0.0000E+00 About reinf CG
Inertia = 3.4439E+03 About composite CG

TRANSFORMED CONCRETE SECTION:

Area = 7.6145E+02
Ybar = 1.9388E+01
Inertia = 1.2649E+05

INTERACTION DIAGRAM

Moments about centroid of gross concrete section
(Units = K-ft)

c	Mn	Pn	
	0.0	-624.0	Maximum tension
1.95	1168.1	-497.2	
3.90	1319.1	-370.4	
5.85	1452.6	-243.6	
7.80	1568.6	-116.8	
9.75	1627.1	-42.5	

STRUCTWARE

SHEET C5-4 OF

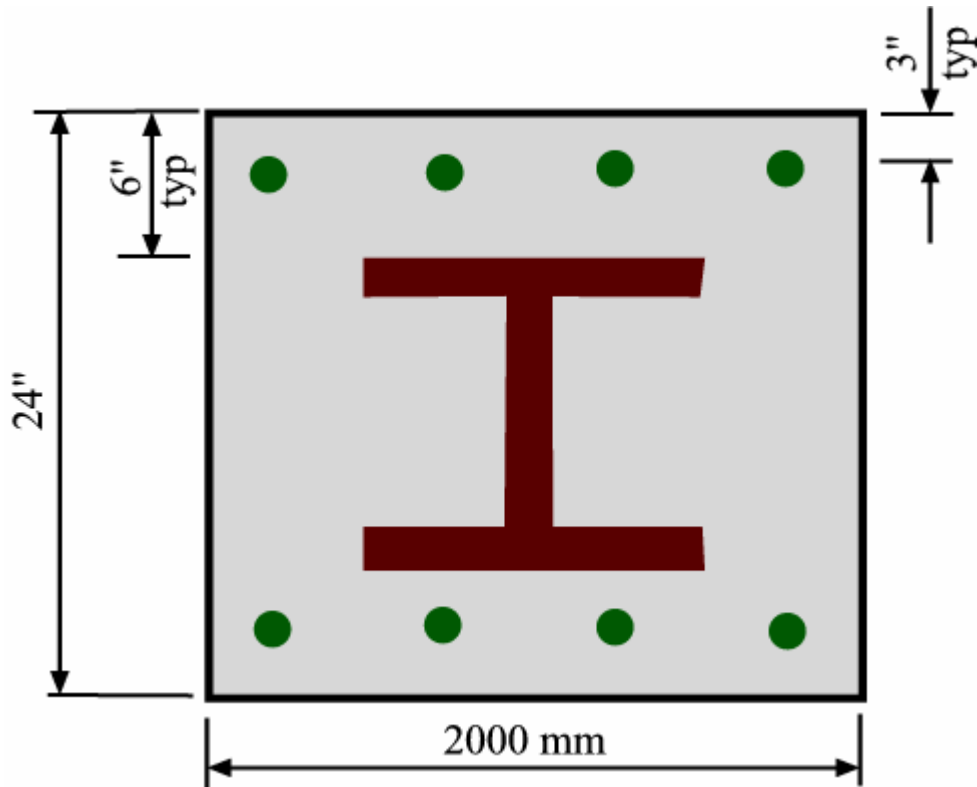
JOB TITLE Verification Problem No. 5 ORIGINATOR RM DATE 4/7/2004

JOB No. CALCULATION No. REVIEWER DATE

11.16	1654.8	0.3	Pure bending
11.70	1664.8	16.6	
13.65	1694.4	75.8	
15.60	1715.9	135.0	
17.55	1729.1	194.2	
19.50	1734.2	253.3	
21.45	1731.1	312.5	
22.87	1722.6	356.3	Balanced strain
23.40	1656.7	411.1	
25.35	1431.5	598.7	
27.30	1227.4	768.1	
29.25	1038.7	922.7	
31.20	861.0	1065.4	
33.15	690.8	1198.2	
35.10	525.6	1322.9	
37.05	363.2	1440.6	
	0.0	1816.1	Maximum compression

VERIFICATION PROBLEM NO 6

File = VER6.OUT



$f'_c = 4000$ psi

$f_y = 60$ ksi

$f_s = 36$ ksi

(4) #9 bars top and bottom

Steel flanges and web all 1" thick

Member L = 30000 mm k = 1.0

LOAD	P (kN)	M (kN-m)
1	20000	10000

STRUCTWARE

SHEET C6-2 OF _____JOB TITLE Verification Problem No. 6ORIGINATOR RMDATE 4/7/2004

JOB No. _____

CALCULATION No. _____

REVIEWER _____

DATE _____

FILE = VER6.OUT

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12/09/01, 6:07 pm

D E S I G N C R I T E R I A

Design Criteria = ACI-318

Units = English (inches, pounds)

MATERIAL STRENGTH:

Concrete compressive strength	= 4000
Concrete modulus of elasticity	= 3605000
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9E+07
Structural steel yield strength	= 36000
Structural steel modulus of elasticity	= 2.9E+07

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 0.9
Compression and flexure	= 0.7
Shear and torsion	= 0.85

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.85
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 1
Reinforcing	= 1
Structural steel	= 1

C O N C R E T E C O N F I G U R A T I O N

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	24	24	1

STRUCTWARE

SHEET C6-3 OF _____

JOB TITLE Verification Problem No. 6 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

2 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
3	18	0	4	1
21	18	0	4	1

STEEL CONFIGURATION

3 RECTANGULAR SHAPES:

Ytop	Depth	Width
6	1	12
7	10	1
17	1	12

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length = 240

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	0	1
Moment restraint	0	1

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*          O U T P U T   D A T A
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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 5.7600E+02
Ybar = 1.2000E+01
Io = 2.7648E+04 About concrete CG

STRUCTWARE

SHEET C6-4 OF _____JOB TITLE Verification Problem No. 6 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING STEEL:

Area = 8.0000E+00
Ybar = 1.2000E+01
Io = 6.4800E+02 About reinf CG

STEEL SHAPES:

Area = 3.4000E+01
Ybar = 1.2000E+01
Io = 8.1133E+02 About steel CG

TRANSFORMED CONCRETE SECTION:

Area = 8.7186E+02
Ybar = 1.2000E+01
Inertia = 3.7928E+04

I N T E R A C T I O N D I A G R A M

=====

Moments about centroid of gross concrete section
(Units = K-ft)

C	Mn	Pn	
	0.0	-1704.0	Maximum tension
1.17	77.8	-1622.8	
2.34	255.2	-1399.9	
3.51	431.1	-1170.0	
4.68	546.2	-1002.1	
5.85	767.9	-574.7	
7.02	936.3	-229.1	
8.08	1035.4	2.3	Pure bending
8.19	1048.7	29.0	
9.36	1149.3	295.2	
10.53	1218.6	533.7	
11.70	1250.6	725.4	
12.43	1252.0	832.1	Balanced strain
12.87	1214.9	959.1	
14.04	1123.6	1266.6	
15.21	1039.6	1535.7	
16.38	960.1	1775.1	
17.55	883.1	1990.7	
18.72	807.0	2186.7	
19.89	730.6	2366.9	
21.06	670.2	2496.3	
22.23	588.9	2655.3	
23.40	504.8	2804.9	
	0.0	2815.7	Maximum compression

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C6-5 OF _____

TITLE _____

BY RM DATE 2/22/00

• Section properties

Concrete

$$A = (24)^2 = 576$$

$$\bar{Y} = 12$$

$$I_o = (24)^4 / 12 = 27648$$

Reinforcing

$$A = 8$$

$$\bar{Y} = 12$$

$$I_o = 2(4)(9)^2 = 648$$

Steel

$$A = 34$$

$$\bar{Y} = 12$$

$$I_o = \frac{2(12)(1)^3}{12} + \frac{1(10)^3}{12} + 2(12)(5.5)^2 = 811.3$$

Transformed

$$A = 576 + 7.044(8) + 7.044(34) = 871.8$$

$$\bar{Y} = 12$$

$$I = 27648 + 7.044(648) + 7.044(811.3) = 37927$$

• Interaction diagram

a) Max tension

$$P_n = (8 \times 60 + 34 \times 36) = 1704$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET CG-6 OF _____

TITLE _____

BY RM DATE 2/23/00

b) Pure bending

$$C = 8.08$$

$$.85 f'_c = 3400$$

$$a = 8.08 \times .85 = 6.87$$

$$\text{Bottom reinf: } T = 4 \times 60000 = -240000$$

$$\text{Top reinf: } \sigma = .003 \frac{(3 - 8.08)(29 \times 10^6)}{8.08} = -54698$$

$$C = 4 \times (54698 - 3400) = +205192$$

$$\text{Concrete: } C = 6.87 \times 24 \times 3400 = +560592$$

$$\text{Top Plange: } \sigma = .003 \frac{(6.5 - 8.08)(29 \times 10^6)}{8.08} = 17012$$

$$C = 12 \times (17012 - 3400) = +163349$$

$$\text{Bottom Plange: } T = 12 \times 36000 = -432000$$

Web: begins to yield at 11.42
stress is zero at 8.08

$$7 < c < 8.08 \quad (7.54)$$

$$\sigma = .003 \frac{(7.54 - 8.08)(29 \times 10^6)}{8.08} = 5814$$

$$C = 1.08(5814) = +6280$$

$$8.08 < c < 11.42 \quad (9.75)$$

$$\sigma = .003 \frac{(9.75 - 8.08)(29 \times 10^6)}{8.08} = 17981$$

$$T = 3.34(17981) = -60058$$

$$11.42 < c < 17 \quad (14.21)$$

$$T = 5.58(36000) = -200880$$

$$\Sigma F = 2475$$

$$\Sigma M = [-240(21) + 205.192(3) + 560.592(3.43) + 163.349(6.5) - 432(17.5) + 6.28(7.54) - 60.058(9.75) - 200.88(14.21)] / 12 = 1032.7$$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET CG-7 OF _____

TITLE _____

BY Rm DATE 2/23/00

c) Balanced strain

$$X_b = \frac{.003 \times 21}{\frac{60000}{29 \times 10^6} + .003} = 12.43$$

d) Max compression

$$P_n = 0.8 \left[\frac{0.85 \times 4000 (576 - 8 - 34) + 8 \times 60^k + 34 \times 36^k}{1000} \right] = 2815.7$$

STRUCTWARE

SHEET C7-1 OF

JOB TITLE Verification Problem No. 7 ORIGINATOR RM DATE 4/7/2004

JOB No. CALCULATION No. REVIEWER DATE

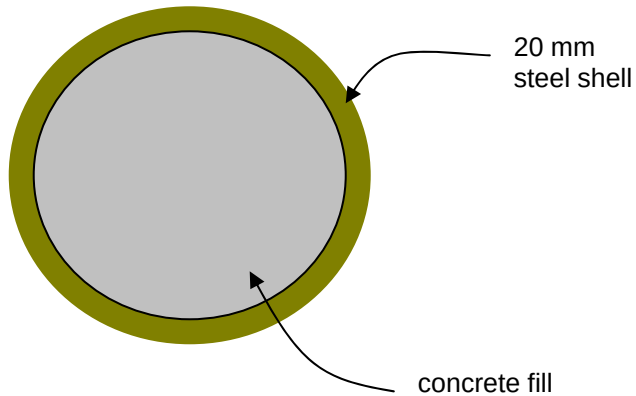
VERIFICATION PROBLEM NO 7

File = VER7.OUT

$f'_c = 30 \text{ MPa}$
 $f_s = 240 \text{ MPa}$

$\alpha_1 = 0.85$
 $\beta_1 = 0.84$

Radius to center of shell = 524 mm



STRUCTWARE

SHEET C7-2 OF _____

JOB TITLE Verification Problem No. 7 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

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12/09/01, 6:28 pm

D E S I G N C R I T E R I A

Design Criteria = AASHTO LRFD
Units = Metric (millimeters, Newtons)

MATERIAL STRENGTH:

Concrete compressive strength = 30
Concrete modulus of elasticity = 26291
Structural steel yield strength = 240
Structural steel modulus of elasticity = 200000

STRENGTH REDUCTION FACTORS:

Tension and flexure = 0.9
Compression and flexure = 0.75
Shear and torsion = 0.9

STRESS BLOCK:

Ratio of average concrete strength = 0.85
Ratio of depth of compression block = 0.84
Maximum concrete strain = 0.003

RESISTANCE FACTORS:

Concrete = 1
Structural steel = 1

C O N C R E T E C O N F I G U R A T I O N

1 CIRCULAR SECTIONS:

Ycenter	Radius	Add
534	514	1

STEEL CONFIGURATION

1 PIPE SHAPES:

Ycenter	Radius	Thickness
534	524	20

* P R O G R A M C O N S E C *		
* O U T P U T D A T A *		

SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area	= 8.3000E+05
Ybar	= 5.3400E+02
Io	= 5.4821E+10 About concrete CG

STEEL SHAPES:

Area	= 6.5848E+04
Ybar	= 5.3400E+02
Io	= 9.0434E+09 About steel CG

TRANSFORMED CONCRETE SECTION:

Area	= 1.3309E+06
Ybar	= 5.3400E+02
Inertia	= 1.2362E+11

INTERACTION DIAGRAM

Moments about centroid of gross concrete section
(Units = kN-m)

C	Mn	Pn	Maximum tension
	0.0	-15803.5	
52.00	2114.4	-11648.7	
104.00	3260.6	-9143.6	
156.00	4163.3	-6930.2	
208.00	4923.7	-4814.2	
260.00	5571.0	-2731.7	

STRUCTWARE

SHEET C7-4 OF _____

JOB TITLE Verification Problem No. 7 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

312.00	6119.5	-647.5	
329.00	6262.0	22.5	Pure bending
364.00	6565.5	1426.5	
416.00	6915.1	3515.7	
468.00	7165.3	5634.2	
520.00	7312.9	7773.3	
572.00	7355.4	9933.1	
624.00	7282.4	12137.5	
676.00	7086.8	14388.5	
728.00	6740.9	16736.2	
763.00	6370.6	18467.7	Balanced strain
780.00	6151.7	19344.9	
832.00	5496.6	21867.4	
884.00	4857.3	24163.0	
936.00	4230.3	26253.8	
988.00	3615.6	28153.6	
1040.00	3016.8	29868.8	
	0.0	29995.9	Maximum compression

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C7-5 OF _____

TITLE _____

BY Rm DATE 2/24/00

• Section Properties

$$n = 200000 / 26291 = 7.607$$

Concrete

$$A = \pi (514)^2 = 829996$$

$$\bar{Y} = 534$$

$$I_o = \frac{\pi}{4} (514)^4 = 5.4820 \times 10^{10}$$

Steel

$$A = \pi [(534)^2 - (514)^2] = 65848$$

$$\bar{Y} = 534$$

$$I_o = \frac{\pi}{4} [(534)^4 - (514)^4] = 9.0434 \times 10^9$$

Transformed

$$A = 829996 + 7.607 (65848) = 1.3309 \times 10^6$$

$$\bar{Y} = 534$$

$$I = 5.482 \times 10^{10} + 7.607 (9.0434 \times 10^9) = 1.2361 \times 10^{11}$$

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SHEET C7-6 OF _____

TITLE _____

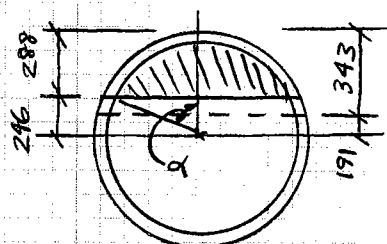
BY Rm DATE 2/24/00

• Interaction diagram

a) Max tension $P_n = \frac{65848 \times 240}{1000} = 15804 \text{ kN}$

b) $c = 343$

$a = .84 \times 343 = 288$



$\alpha = \cos^{-1}\left(\frac{246}{514}\right) = 61.406^\circ (1.072 \text{ rad})$

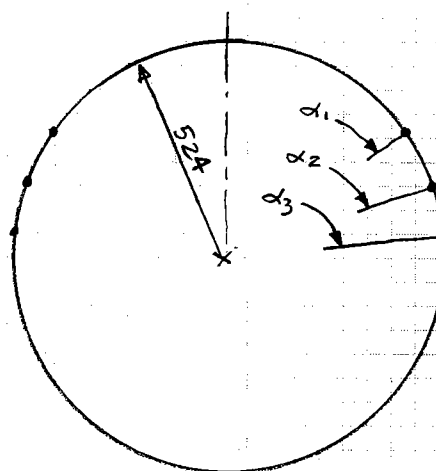
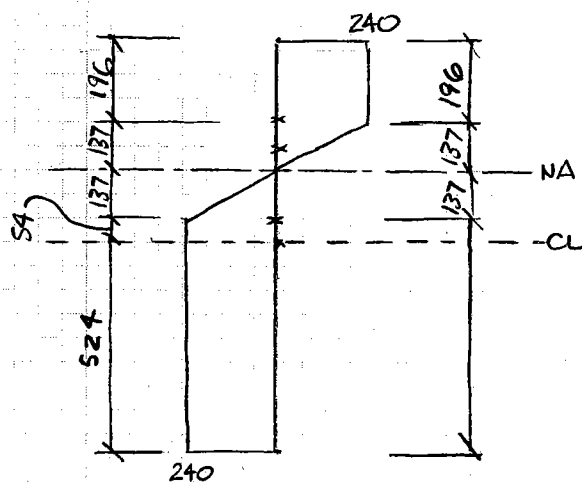
$A_c = (1028)^2 \left[\frac{1.072 - 5 \sin 61.4 \cos 61.4}{4} \right] = 172127$

$C_c = 172127 \times .85 \times 30 = 4.3892 \times 10^6 \text{ N}$

$\bar{y} = \frac{534^3 - (1028)^3 \sin^3 61.4}{12(172127)} = 178 \text{ (from extreme compression)}$

Steel yields at 137 from NA

Calculate force in steel



$\alpha_1 = \cos^{-1}(328/524) = 51.25^\circ (.8944 \text{ r})$

$\alpha_2 = \cos^{-1}(191/524) = 68.62^\circ (1.198 \text{ r})$

$\alpha_3 = \cos^{-1}(54/524) = 84.08^\circ (1.468 \text{ r})$

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C7-7 OF _____

TITLE _____

BY LM DATE 2/24/00

> For segment 1

$$\text{Area} = 2 \alpha r t = 2 (.8944)(524)(20) = 18747$$

$$\bar{y} = 534 - \frac{2r \sin(\frac{\alpha}{2}) \cos(\frac{\alpha}{2})}{\alpha} = \frac{2(524)(.3899)}{.8944} + 534 = 77$$

> For segment 2

$$A = 2 r t (1.198 - .8944) = 6363$$

$$\text{due to varying stress, use } \bar{y} = 206 + 137/3 = 252$$

> For segment 3

$$A = 2 r t (1.468 - 1.198) = 5659$$

$$\text{due to varying stress, use } \bar{y} = 343 + 2(137)/3 = 434$$

> For segment 4

$$A = 2 r t (1.5708 - 1.468) = 2155 \quad \Theta = 1.5194$$

$$\bar{y} = 534 - \frac{2(524) \sin(.0514) \cos(1.5194)}{.1028} = 507$$

> For segment 5

$$A = \pi (524)(20) = 32924$$

$$\bar{y} = 534 + \frac{2(524)}{\pi} = 868$$

Segment	Force	FY
1	$18747 (240) =$	4.4993×10^6
2	$6363 (240/2) =$	7.6356×10^5
3	$-5659 (240/2) =$	-6.7908×10^5
4	$-2155 (240) =$	-5.1720×10^5
5	$-32924 (240) =$	-7.9018×10^6
		-3.8352×10^6
		-6.8768×10^9

**STEEL PIPE WITH CONCRETE CORE
INTERACTION DIAGRAM CALCULATIONS
PURE BENDING WITH $c + Y_d < R$**

Steel pipe

Concrete core

CL "Y0" = 534 Radius = 514 F factor = 1000
 Radius = 524 f'c = 30 M factor = 1000000
 Thickness = 20 a1 = 0.85
 fy = 240 b1 = 0.84
 Es = 200000 em = 0.003

NA "c" = 329 a = 276

Concrete: alpha = 1.046
 Area = 161696
 Force = 4123239
 Ybar = 171

Pipe: Yield distance = 132 Note: $c + Y_d < R$ OK

No	Angle
1	0.8732
2	1.1688
3	1.4303

Segment	Alpha	Theta	Area	Ybar	Force	FY
1	0.4366	0.4366	18303	74	4.3926E+06	3.2549E+08
2	0.1478	1.0210	6196	283	7.4355E+05	2.1053E+08
3	0.1307	1.2995	5479	372	-6.5752E+05	-2.4464E+08
4	0.0703	1.5005	2946	497	-7.0696E+05	-3.5153E+08
5			32924	868	-7.9017E+06	-6.8555E+09
Total					-4.1301E+06	-6.9156E+09

Section: P = -6.8
 M = 6209.5

**STEEL PIPE WITH CONCRETE CORE
INTERACTION DIAGRAM CALCULATIONS
AXIAL LOAD AND BENDING WITH $c + Y_d < R$**

Steel pipe

Concrete core

CL "Y0" = 534 Radius = 514 F factor = 1000
 Radius = 524 $f_c = 30$ M factor = 1000000
 Thickness = 20 $a_1 = 0.85$
 $f_y = 240$ $b_1 = 0.84$
 $E_s = 200000$ $e_m = 0.003$

NA "c" = 260 a = 218

Concrete: $\alpha = 0.910$
 Area = 112292
 Force = 2863438
 $\bar{Y} = 138$

Pipe: Yield distance = 104 Note: $c + Y_d < R$ OK

No	Angle
1	0.7650
2	1.0205
3	1.2404

Segment	Alpha	Theta	Area	Ybar	Force	FY
1	0.3825	0.3825	16035	60	3.848E+06	2.295E+08
2	0.1278	0.8928	5356	224	6.427E+05	1.437E+08
3	0.1099	1.1305	4608	294	-5.530E+05	-1.624E+08
4	0.1652	1.4056	6925	448	-1.662E+06	-7.450E+08
5			32924	868	-7.902E+06	-6.855E+09
Total					-5.626E+06	-7.390E+09

Section: P = -2762.3
 $\bar{Y} = 2532.608$
 e = -1998.608
 M = 5520.7

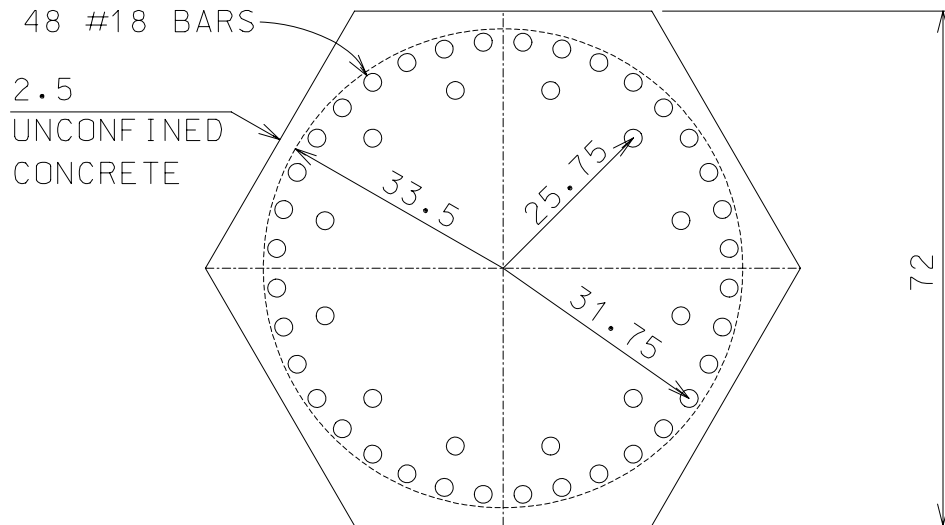
VERIFICATION PROBLEM NO 8
CHECK OF INTERACTION DIAGRAM

C	MOMENT			AXIAL LOAD		
	CONSEC	CHECK	DIFF	CONSEC	CHECK	DIFF
52	2114	2091	1%	-11649	-11689	0%
104	3261	3240	1%	-9144	-9167	0%
156	4163	4135	1%	-6930	-6956	0%
208	4924	4885	1%	-4814	-4843	-1%
260	5571	5521	1%	-2732	-2762	-1%
312	6120	6054	1%	-648	-687	-6%
329	6262	6210	1%	23	-7	130%
364	6566	6486	1%	1427	1397	2%

VERIFICATION PROBLEM NO 8

File = VER8.OUT

Calculate moment curvature using Caltrans XSECTION program as check for CONSEC.



PIER 96 COLUMN

Axial load = 502 kips

Mander confined concrete model:

$$e_0 = 0.002$$

$$f_0 = 3900 \text{ psi}$$

$$e_u = 0.005$$

Confinement is #5 spirals at 2.75"

Park complex reinforcing model:

$$e_y = 0.00138$$

$$f_y = 40000 \text{ psi}$$

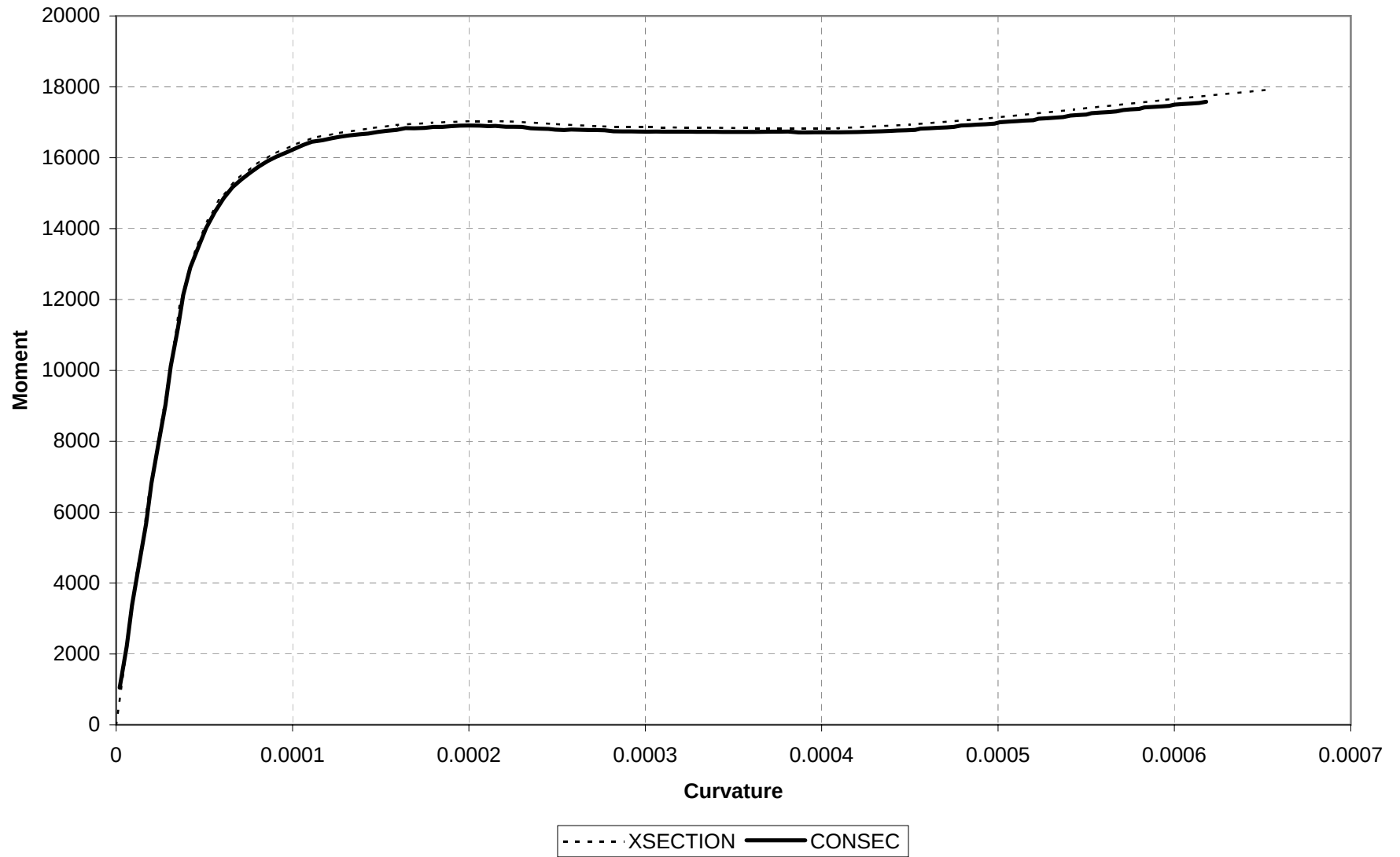
$$e_h = 0.019$$

$$f_h = 40000 \text{ psi}$$

$$e_u = 0.12$$

$$f_u = 60000 \text{ psi}$$

72" Circular Column Moment Curvature



STRUCTWARE

SHEET C8-3 OF JOB TITLE Verification Problem No. 8ORIGINATOR RMDATE 4/7/2004JOB No. CALCULATION No. REVIEWER DATE

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12/09/01, 7:05 pm

S T R E S S - S T R A I N I N F O R M A T I O N

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CONCRETE MODEL:

Mander concrete model

```
Unconfined strain    = 0.002
Unconfined stress    = 3900
Modulus of elasticity = 3559649
Ultimate strain      = 0.01335
Ultimate stress      = 0
Spalling strain      = 0.005
Confined stress      = 4786.4
```

Spiral confinement:

```
Bar diameter        = 0.625
Long spacing        = 2.75
Concrete cover      = 2.5
Yield strength      = 40000
Ultimate strain     = 0.12
Spiral diameter     = 67
```

REINFORCING MODEL:

Park reinforcing model
(with complex strain hardening)

Point	Strain	Stress
1	-0.12	-60000
2	-0.01932	-40000
3	-0.00138	-40000
4	0.00138	40000
5	0.01932	40000
6	0.12	60000

C O N C R E T E C O N F I G U R A T I O N

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1 CIRCULAR SECTIONS:

Ycenter	Radius	Add
36	36	1

STRUCTWARE

SHEET C8-4 OF _____JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

2 REINFORCING ARCS:

Ycenter	Radius	Abeg	Atot	Nbar	Abar
36	31.75	0	350	36	4
36	25.75	0	330	12	4

LOAD CONDITIONS

(Units = K-ft)

1 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	502.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length = 200

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	0	1
Moment restraint	0	1

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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 4.0715E+03
Ybar = 3.6000E+01
Io = 1.3192E+06 About concrete CG

REINFORCING STEEL:

Area = 1.9200E+02
Ybar = 3.6000E+01
Io = 8.8494E+04 About reinf CG

STRUCTWARE

SHEET C8-5 OF _____JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

TRANSFORMED CONCRETE SECTION:

Area = 5.6630E+03
Ybar = 3.6000E+01
Inertia = 2.0527E+06

M O M E N T C U R V A T U R E

=====

Moments about centroid of gross concrete section
(Units = K-ft)

Load Condition Number 1
Axial Load = 502.0

Strain	c	Axial	Curvature	Moment
0.00010	45.05	503.0	0.000002	1046.6
0.00020	34.70	503.5	0.000006	2210.0
0.00030	31.85	502.1	0.000009	3372.0
0.00040	30.60	505.9	0.000013	4527.1
0.00050	29.90	508.6	0.000017	5672.5
0.00060	29.45	507.4	0.000020	6807.1
0.00070	29.15	504.0	0.000024	7928.0
0.00080	29.00	514.9	0.000028	9028.5
0.00090	28.85	509.2	0.000031	10119.2
0.00100	28.75	503.7	0.000035	11192.8
0.00110	28.60	517.8	0.000038	12129.3
0.00120	28.25	512.1	0.000042	12903.1
0.00130	27.80	510.2	0.000047	13526.1
0.00140	27.25	503.4	0.000051	14015.8
0.00150	26.80	513.3	0.000056	14475.0
0.00160	26.30	508.2	0.000061	14861.9
0.00170	25.80	505.2	0.000066	15170.8
0.00180	25.35	505.9	0.000071	15385.1
0.00190	25.00	507.5	0.000076	15577.6
0.00200	24.70	505.7	0.000081	15756.1
0.00210	24.40	511.7	0.000086	15906.8
0.00220	24.15	514.7	0.000091	16031.6
0.00230	23.90	506.2	0.000096	16136.7
0.00240	23.70	505.1	0.000101	16246.9
0.00250	23.55	510.5	0.000106	16357.1
0.00260	23.40	515.4	0.000111	16451.8
0.00270	23.15	510.5	0.000117	16494.7
0.00280	22.95	513.1	0.000122	16545.9
0.00290	22.80	518.2	0.000127	16593.3
0.00300	22.65	516.9	0.000132	16629.9
0.00310	22.50	512.7	0.000138	16660.7
0.00320	22.35	502.9	0.000143	16683.1
0.00330	22.25	507.3	0.000148	16722.5
0.00340	22.15	507.7	0.000153	16755.6
0.00350	22.05	504.3	0.000159	16782.7
0.00360	22.00	520.6	0.000164	16832.5
0.00370	21.85	508.2	0.000169	16831.8
0.00380	21.75	505.2	0.000175	16840.8
0.00390	21.70	517.3	0.000180	16869.7
0.00400	21.60	509.0	0.000185	16870.1
0.00410	21.55	516.4	0.000190	16890.3
0.00420	21.50	520.7	0.000195	16903.9

Reinf tens yield

Reinf comp yield

STRUCTWARE

SHEET C8-6 OF _____

JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

0.00430	21.45	520.7	0.000200	16907.3	
0.00440	21.40	517.6	0.000206	16903.4	
0.00450	21.35	510.3	0.000211	16890.1	
0.00460	21.35	521.3	0.000215	16898.7	
0.00470	21.30	509.2	0.000221	16874.8	
0.00480	21.30	516.0	0.000225	16873.7	
0.00490	21.30	521.6	0.000230	16870.1	
0.00500	21.25	502.8	0.000235	16831.7	
0.00510	21.25	505.5	0.000240	16821.6	Conc spalling
0.00520	21.25	507.2	0.000245	16811.2	
0.00530	21.25	504.0	0.000249	16793.0	
0.00540	21.25	502.0	0.000254	16779.3	
0.00550	21.30	521.9	0.000258	16794.6	
0.00560	21.30	522.5	0.000263	16789.3	
0.00570	21.30	522.4	0.000268	16782.5	
0.00580	21.30	523.4	0.000272	16779.3	
0.00590	21.30	523.8	0.000277	16775.0	
0.00600	21.25	502.2	0.000282	16744.7	
0.00610	21.25	502.5	0.000287	16741.7	
0.00620	21.25	503.5	0.000292	16740.6	
0.00630	21.25	504.0	0.000296	16739.0	
0.00640	21.25	504.0	0.000301	16736.2	
0.00650	21.25	505.0	0.000306	16736.5	
0.00660	21.25	505.4	0.000311	16735.7	
0.00670	21.25	505.0	0.000315	16733.0	
0.00680	21.25	505.7	0.000320	16733.3	
0.00690	21.25	506.0	0.000325	16733.0	
0.00700	21.25	505.5	0.000329	16731.0	
0.00710	21.25	505.5	0.000334	16730.3	
0.00720	21.25	505.3	0.000339	16729.7	
0.00730	21.25	504.9	0.000344	16728.4	
0.00740	21.25	504.3	0.000348	16727.0	
0.00750	21.25	503.8	0.000353	16726.1	
0.00760	21.25	505.6	0.000358	16727.0	
0.00770	21.25	508.8	0.000362	16728.8	
0.00780	21.25	512.1	0.000367	16731.2	
0.00790	21.25	515.5	0.000372	16734.1	
0.00800	21.25	518.4	0.000376	16735.7	
0.00810	21.25	520.9	0.000381	16736.9	
0.00820	21.20	503.3	0.000387	16711.9	
0.00830	21.20	506.3	0.000392	16714.3	
0.00840	21.20	509.0	0.000396	16716.4	
0.00850	21.20	511.3	0.000401	16717.4	
0.00860	21.20	513.0	0.000406	16717.5	
0.00870	21.20	514.7	0.000410	16717.5	
0.00880	21.20	516.9	0.000415	16718.9	
0.00890	21.20	517.9	0.000420	16722.7	
0.00900	21.20	517.2	0.000425	16730.2	
0.00910	21.20	516.3	0.000429	16737.2	
0.00920	21.20	514.4	0.000434	16743.8	
0.00930	21.20	511.7	0.000439	16754.3	
0.00940	21.20	509.0	0.000443	16765.0	
0.00950	21.20	506.3	0.000448	16775.3	
0.00960	21.20	503.5	0.000453	16785.1	
0.00970	21.25	523.5	0.000456	16818.7	
0.00980	21.25	519.3	0.000461	16830.8	
0.00990	21.25	514.9	0.000466	16843.6	

STRUCTWARE

SHEET C8-7 OF _____JOB TITLE Verification Problem No. 8ORIGINATOR RMDATE 4/7/2004

JOB No. _____ CALCULATION No. _____

REVIEWER _____

DATE _____

0.01000	21.25	510.6	0.000471	16856.2
0.01010	21.25	506.1	0.000475	16868.4
0.01020	21.30	528.3	0.000479	16907.6
0.01030	21.30	523.1	0.000484	16920.7
0.01040	21.30	517.8	0.000488	16933.5
0.01050	21.30	512.5	0.000493	16945.8
0.01060	21.30	507.0	0.000498	16960.8
0.01070	21.35	528.8	0.000501	17002.1
0.01080	21.35	522.3	0.000506	17017.0
0.01090	21.35	515.8	0.000511	17031.5
0.01100	21.35	509.2	0.000515	17045.6
0.01110	21.35	502.6	0.000520	17059.3
0.01120	21.40	524.3	0.000523	17098.5
0.01130	21.40	516.8	0.000528	17114.8
0.01140	21.40	509.5	0.000533	17131.4
0.01150	21.40	502.2	0.000537	17147.6
0.01160	21.45	524.0	0.000541	17188.6
0.01170	21.45	516.4	0.000545	17203.5
0.01180	21.45	508.8	0.000550	17218.1
0.01190	21.50	530.1	0.000553	17257.1
0.01200	21.50	521.3	0.000558	17273.3
0.01210	21.50	512.7	0.000563	17289.5
0.01220	21.50	504.5	0.000567	17306.1
0.01230	21.55	526.0	0.000571	17346.7
0.01240	21.55	518.0	0.000575	17362.8
0.01250	21.55	509.9	0.000580	17378.7
0.01260	21.60	531.5	0.000583	17418.2
0.01270	21.60	523.3	0.000588	17433.1
0.01280	21.60	515.1	0.000593	17447.5
0.01290	21.60	506.8	0.000597	17461.7
0.01300	21.65	528.0	0.000600	17499.2
0.01310	21.65	520.4	0.000605	17513.8
0.01320	21.65	512.8	0.000610	17528.2
0.01330	21.65	505.3	0.000614	17542.3
0.01340	21.70	527.2	0.000618	17580.2

Yield curvature = 3.8462E-05
Ultimate curvature = 6.1751E-04
Idealized plastic moment = 16674.8
Maximum tension = -5271. At moment = 17542.3

Cracked moment of inertia = 1.0631E+06
Based on 1st yield strain = -0.00151

LOCAL MEMBER DUCTILITY:

Idealized yield curvature = 5.2875E-05
Plastic hinge length = 29.5
Yield deflection = 0.705
Ultimate deflection = 3.795
Local member ductility = 5.4

CHECKED _____ DATE _____

JOB NO. _____

APPROVED _____ DATE _____

SHEET C8-8 OF _____

TITLE _____

BY Rm DATE 4/17/00

- Calculate ultimate stress and strain

$$f'_{cc} = 3900 \left(2.254 \sqrt{1 + \frac{7.94(129.1)}{3900}} - \frac{2(129.1)}{3900} - 1.254 \right) = 4730$$

$$\epsilon_{cc} = .002 \left(1 + 5 \left(\frac{4730}{3900} - 1 \right) \right) = .00413$$

$$f'_l = \frac{2(40000)(.31)}{2.75(67)} = 134.6$$

$$A_{cc} = \pi (67)^2 / 4 = 3526$$

$$d_e = 67 - 2.75 / 2 = 65.625$$

$$A_e = \frac{\pi}{4} (65.625)^2 = 3382$$

$$k_e = \frac{3382}{3526} = 0.959$$

$$f'_g = 0.959(134.6) = 129.1$$

$$\rho_s = \frac{.31 \times 4}{67 \times 2.75} = .00673$$

$$\epsilon_{cu} = .004 + \frac{1.4(.00673)(40000)(.12)}{4730} = .01356$$

STRUCTWARE

SHEET C8-9 OF _____JOB TITLE Verification Problem No. 8ORIGINATOR RMDATE 4/7/2004

JOB No. _____ CALCULATION No. _____

REVIEWER _____

DATE _____

FILE = VER8MCX.OUT

03/30/2000, 12:21

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*****
*
*                                     xSECTION
*
*          DUCTILITY and STRENGTH of
*    Circular, Semi-Circular, full and partial Rings,
*    Rectangular, T-, I-, Hammer head, Octagonal, Polygons
*    or any combination of above shapes forming
*    Concrete Sections using Fiber Models
*
* VER._2.11,_MAY-06-95
*
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LICENSE (choices: LIMITED/UNLIMITED)

LIMITED

ENTITY (choices: GOVERNMENT/CONSULTANT)

CONSULTANT

NAME_OF_FIRM

ZIPPY_ENGINEERING

BRIDGE_NAME

ROCKET_AVE.

BRIDGE_NUMBER

123-456

JOB_TITLE

rect w/mirror

Concrete Type Information:

	-----strains-----				-----strength-----					
Type	e0	e2	ecc	eu	f0	f2	fcc	fu	E	W
1	0.0020	0.0040	0.0042	0.0140	3.90	4.77	4.77	3.71	3561	144
2	0.0020	0.0040	0.0020	0.0050	3.90	2.95	3.90	2.50	3561	144

STRUCTWARE

SHEET C8-10 OF _____

JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

Steel Type Information:

Type	-----strains-----			--strength--		E
	ey	eh	eu	fy	fu	
1	0.0014	0.0190	0.1200	40.00	60.00	29000
2	0.0023	0.0110	0.0900	68.00	95.00	29000

Concrete Fiber Information:

Fiber No.	type	xc in	yc in	area in^2
1	1	1.55	0.64	4.41
2	1	0.64	1.55	4.41
3	1	-0.64	1.55	4.41
4	1	-1.55	0.64	4.41
5	1	-1.55	-0.64	4.41
6	1	-0.64	-1.55	4.41
7	1	0.64	-1.55	4.41
8	1	1.55	-0.64	4.41
9	1	4.78	1.55	10.58
10	1	2.95	4.07	10.58
11	1	0.00	5.02	10.58
12	1	-2.95	4.07	10.58
13	1	-4.78	1.55	10.58
14	1	-4.78	-1.55	10.58
15	1	-2.95	-4.07	10.58
16	1	0.00	-5.02	10.58
17	1	2.95	-4.07	10.58
18	1	4.78	-1.55	10.58
19	1	8.13	2.00	13.56
20	1	6.27	5.55	13.56
21	1	2.97	7.83	13.56
22	1	-1.01	8.31	13.56
23	1	-4.76	6.89	13.56
24	1	-7.42	3.89	13.56
25	1	-8.38	0.00	13.56
26	1	-7.42	-3.89	13.56
27	1	-4.76	-6.89	13.56
28	1	-1.01	-8.31	13.56
29	1	2.97	-7.83	13.56
30	1	6.27	-5.55	13.56
31	1	8.13	-2.00	13.56
32	1	11.50	2.29	15.42
33	1	9.75	6.51	15.42
34	1	6.51	9.75	15.42
35	1	2.29	11.50	15.42
36	1	-2.29	11.50	15.42
37	1	-6.51	9.75	15.42
38	1	-9.75	6.51	15.42
39	1	-11.50	2.29	15.42

STRUCTWARE

SHEET C8-11 OF _____JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

40	1	-11.50	-2.29	15.42
41	1	-9.75	-6.51	15.42
42	1	-6.51	-9.75	15.42
43	1	-2.29	-11.50	15.42
44	1	2.29	-11.50	15.42
45	1	6.51	-9.75	15.42
46	1	9.75	-6.51	15.42
47	1	11.50	-2.29	15.42
48	1	14.87	2.48	16.70
49	1	13.26	7.17	16.70
50	1	10.21	11.09	16.70
51	1	6.06	13.81	16.70
52	1	1.24	15.02	16.70
53	1	-3.70	14.61	16.70
54	1	-8.25	12.62	16.70
55	1	-11.90	9.26	16.70
56	1	-14.26	4.89	16.70
57	1	-15.07	0.00	16.70
58	1	-14.26	-4.89	16.70
59	1	-11.90	-9.26	16.70
60	1	-8.25	-12.62	16.70
61	1	-3.70	-14.61	16.70
62	1	1.24	-15.02	16.70
63	1	6.06	-13.81	16.70
64	1	10.21	-11.09	16.70
65	1	13.26	-7.17	16.70
66	1	14.87	-2.48	16.70
67	1	18.24	2.62	17.63
68	1	16.76	7.65	17.63
69	1	13.92	12.07	17.63
70	1	9.96	15.50	17.63
71	1	5.19	17.68	17.63
72	1	0.00	18.42	17.63
73	1	-5.19	17.68	17.63
74	1	-9.96	15.50	17.63
75	1	-13.92	12.07	17.63
76	1	-16.76	7.65	17.63
77	1	-18.24	2.62	17.63
78	1	-18.24	-2.62	17.63
79	1	-16.76	-7.65	17.63
80	1	-13.92	-12.07	17.63
81	1	-9.96	-15.50	17.63
82	1	-5.19	-17.68	17.63
83	1	0.00	-18.42	17.63
84	1	5.19	-17.68	17.63
85	1	9.96	-15.50	17.63
86	1	13.92	-12.07	17.63
87	1	16.76	-7.65	17.63
88	1	18.24	-2.62	17.63
89	1	21.59	2.84	19.10
90	1	20.12	8.33	19.10

STRUCTWARE

SHEET C8-12 OF _____JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

91	1	17.28	13.26	19.10
92	1	13.26	17.28	19.10
93	1	8.33	20.12	19.10
94	1	2.84	21.59	19.10
95	1	-2.84	21.59	19.10
96	1	-8.33	20.12	19.10
97	1	-13.26	17.28	19.10
98	1	-17.28	13.26	19.10
99	1	-20.12	8.33	19.10
100	1	-21.59	2.84	19.10
101	1	-21.59	-2.84	19.10
102	1	-20.12	-8.33	19.10
103	1	-17.28	-13.26	19.10
104	1	-13.26	-17.28	19.10
105	1	-8.33	-20.12	19.10
106	1	-2.84	-21.59	19.10
107	1	2.84	-21.59	19.10
108	1	8.33	-20.12	19.10
109	1	13.26	-17.28	19.10
110	1	17.28	-13.26	19.10
111	1	20.12	-8.33	19.10
112	1	21.59	-2.84	19.10
113	1	24.96	2.92	19.59
114	1	23.61	8.59	19.59
115	1	20.99	13.81	19.59
116	1	17.24	18.28	19.59
117	1	12.56	21.76	19.59
118	1	7.21	24.07	19.59
119	1	1.46	25.08	19.59
120	1	-4.36	24.74	19.59
121	1	-9.95	23.07	19.59
122	1	-15.00	20.15	19.59
123	1	-19.25	16.15	19.59
124	1	-22.45	11.28	19.59
125	1	-24.45	5.79	19.59
126	1	-25.12	0.00	19.59
127	1	-24.45	-5.79	19.59
128	1	-22.45	-11.28	19.59
129	1	-19.25	-16.15	19.59
130	1	-15.00	-20.15	19.59
131	1	-9.95	-23.07	19.59
132	1	-4.36	-24.74	19.59
133	1	1.46	-25.08	19.59
134	1	7.21	-24.07	19.59
135	1	12.56	-21.76	19.59
136	1	17.24	-18.28	19.59
137	1	20.99	-13.81	19.59
138	1	23.61	-8.59	19.59
139	1	24.96	-2.92	19.59
140	1	28.32	2.98	19.98
141	1	27.08	8.80	19.98

STRUCTWARE

SHEET C8-13 OF _____JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

142	1	24.66	14.24	19.98
143	1	21.16	19.05	19.98
144	1	16.74	23.04	19.98
145	1	11.58	26.01	19.98
146	1	5.92	27.85	19.98
147	1	0.00	28.47	19.98
148	1	-5.92	27.85	19.98
149	1	-11.58	26.01	19.98
150	1	-16.74	23.04	19.98
151	1	-21.16	19.05	19.98
152	1	-24.66	14.24	19.98
153	1	-27.08	8.80	19.98
154	1	-28.32	2.98	19.98
155	1	-28.32	-2.98	19.98
156	1	-27.08	-8.80	19.98
157	1	-24.66	-14.24	19.98
158	1	-21.16	-19.05	19.98
159	1	-16.74	-23.04	19.98
160	1	-11.58	-26.01	19.98
161	1	-5.92	-27.85	19.98
162	1	0.00	-28.47	19.98
163	1	5.92	-27.85	19.98
164	1	11.58	-26.01	19.98
165	1	16.74	-23.04	19.98
166	1	21.16	-19.05	19.98
167	1	24.66	-14.24	19.98
168	1	27.08	-8.80	19.98
169	1	28.32	-2.98	19.98
170	1	31.68	3.03	20.30
171	1	30.54	8.97	20.30
172	1	28.29	14.58	20.30
173	1	25.02	19.67	20.30
174	1	20.84	24.05	20.30
175	1	15.91	27.56	20.30
176	1	10.41	30.07	20.30
177	1	4.53	31.50	20.30
178	1	-1.51	31.79	20.30
179	1	-7.50	30.93	20.30
180	1	-13.22	28.95	20.30
181	1	-18.46	25.92	20.30
182	1	-23.03	21.96	20.30
183	1	-26.77	17.21	20.30
184	1	-29.55	11.83	20.30
185	1	-31.25	6.02	20.30
186	1	-31.82	0.00	20.30
187	1	-31.25	-6.02	20.30
188	1	-29.55	-11.83	20.30
189	1	-26.77	-17.21	20.30
190	1	-23.03	-21.96	20.30
191	1	-18.46	-25.92	20.30
192	1	-13.22	-28.95	20.30

STRUCTWARE

SHEET C8-14 OF _____JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

193	1	-7.50	-30.93	20.30
194	1	-1.51	-31.79	20.30
195	1	4.53	-31.50	20.30
196	1	10.41	-30.07	20.30
197	1	15.91	-27.56	20.30
198	1	20.84	-24.05	20.30
199	1	25.02	-19.67	20.30
200	1	28.29	-14.58	20.30
201	1	30.54	-8.97	20.30
202	1	31.68	-3.03	20.30
203	2	33.98	3.15	7.88
204	2	32.82	9.34	7.88
205	2	30.55	15.21	7.88
206	2	27.23	20.56	7.88
207	2	22.99	25.22	7.88
208	2	17.96	29.01	7.88
209	2	12.33	31.82	7.88
210	2	6.27	33.54	7.88
211	2	0.00	34.12	7.88
212	2	-6.27	33.54	7.88
213	2	-12.33	31.82	7.88
214	2	-17.96	29.01	7.88
215	2	-22.99	25.22	7.88
216	2	-27.23	20.56	7.88
217	2	-30.55	15.21	7.88
218	2	-32.82	9.34	7.88
219	2	-33.98	3.15	7.88
220	2	-33.98	-3.15	7.88
221	2	-32.82	-9.34	7.88
222	2	-30.55	-15.21	7.88
223	2	-27.23	-20.56	7.88
224	2	-22.99	-25.22	7.88
225	2	-17.96	-29.01	7.88
226	2	-12.33	-31.82	7.88
227	2	-6.27	-33.54	7.88
228	2	0.00	-34.12	7.88
229	2	6.27	-33.54	7.88
230	2	12.33	-31.82	7.88
231	2	17.96	-29.01	7.88
232	2	22.99	-25.22	7.88
233	2	27.23	-20.56	7.88
234	2	30.55	-15.21	7.88
235	2	32.82	-9.34	7.88
236	2	33.98	-3.15	7.88
237	2	35.23	3.17	7.94
238	2	34.10	9.41	7.94
239	2	31.87	15.35	7.94
240	2	28.62	20.79	7.94
241	2	24.45	25.57	7.94
242	2	19.49	29.52	7.94
243	2	13.90	32.53	7.94

STRUCTWARE

SHEET C8-15 OF _____

JOB TITLE Verification Problem No. 8 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

244	2	7.87	34.49	7.94
245	2	1.59	35.34	7.94
246	2	-4.75	35.05	7.94
247	2	-10.93	33.64	7.94
248	2	-16.76	31.15	7.94
249	2	-22.06	27.66	7.94
250	2	-26.64	23.27	7.94
251	2	-30.37	18.14	7.94
252	2	-33.12	12.43	7.94
253	2	-34.81	6.32	7.94
254	2	-35.38	0.00	7.94
255	2	-34.81	-6.32	7.94
256	2	-33.12	-12.43	7.94
257	2	-30.37	-18.14	7.94
258	2	-26.64	-23.27	7.94
259	2	-22.06	-27.66	7.94
260	2	-16.76	-31.15	7.94
261	2	-10.93	-33.64	7.94
262	2	-4.75	-35.05	7.94
263	2	1.59	-35.34	7.94
264	2	7.87	-34.49	7.94
265	2	13.90	-32.53	7.94
266	2	19.49	-29.52	7.94
267	2	24.45	-25.57	7.94
268	2	28.62	-20.79	7.94
269	2	31.87	-15.35	7.94
270	2	34.10	-9.41	7.94
271	2	35.23	-3.17	7.94

Steel Fiber Information:

Fiber No.	type	xc in	yc in	area in^2
1	1	31.75	0.00	4.00
2	1	31.27	5.51	4.00
3	1	29.84	10.86	4.00
4	1	27.50	15.88	4.00
5	1	24.32	20.41	4.00
6	1	20.41	24.32	4.00
7	1	15.87	27.50	4.00
8	1	10.86	29.84	4.00
9	1	5.51	31.27	4.00
10	1	0.00	31.75	4.00
11	1	-5.51	31.27	4.00
12	1	-10.86	29.84	4.00
13	1	-15.88	27.50	4.00
14	1	-20.41	24.32	4.00
15	1	-24.32	20.41	4.00
16	1	-27.50	15.87	4.00
17	1	-29.84	10.86	4.00
18	1	-31.27	5.51	4.00

STRUCTWARE

SHEET C8-16 OF

JOB TITLE Verification Problem No. 8

ORIGINATOR RM

DATE 4/7/2004

JOB No. CALCULATION No.

REVIEWER

DATE

19	1	-31.75	0.00	4.00
20	1	-31.27	-5.51	4.00
21	1	-29.84	-10.86	4.00
22	1	-27.50	-15.88	4.00
23	1	-24.32	-20.41	4.00
24	1	-20.41	-24.32	4.00
25	1	-15.87	-27.50	4.00
26	1	-10.86	-29.84	4.00
27	1	-5.51	-31.27	4.00
28	1	0.00	-31.75	4.00
29	1	5.51	-31.27	4.00
30	1	10.86	-29.84	4.00
31	1	15.88	-27.50	4.00
32	1	20.41	-24.32	4.00
33	1	24.32	-20.41	4.00
34	1	27.50	-15.87	4.00
35	1	29.84	-10.86	4.00
36	1	31.27	-5.51	4.00
37	1	25.75	0.00	4.00
38	1	22.30	12.88	4.00
39	1	12.87	22.30	4.00
40	1	0.00	25.75	4.00
41	1	-12.88	22.30	4.00
42	1	-22.30	12.87	4.00
43	1	-25.75	0.00	4.00
44	1	-22.30	-12.88	4.00
45	1	-12.87	-22.30	4.00
46	1	0.00	-25.75	4.00
47	1	12.88	-22.30	4.00
48	1	22.30	-12.87	4.00

Force Equilibrium Condition of the x-section:

step	Max. Conc. Strain epscmax	Neutral Axis in.	Max. Steel Strain Tens.	Conc. Comp.	Steel force Comp. Tens.	P/S force	Net force	Curvature in/in	Moment (K-ft)
0	0.00000	0.00	0.0000	0	0 0	0	0.00	0.000000	0
1	0.00028	4.29	-0.0003	713	374 -585	0	-0.43	0.000009	3245
2	0.00031	4.82	-0.0004	769	407 -674	0	-0.16	0.000010	3599
3	0.00034	5.29	-0.0004	830	443 -772	0	-0.29	0.000011	3988
4	0.00038	5.69	-0.0005	898	484 -880	0	-0.06	0.000012	4418
5	0.00042	6.05	-0.0005	973	530 -1001	0	-0.22	0.000014	4891
6	0.00046	6.36	-0.0006	1055	581 -1134	0	-0.04	0.000016	5412
7	0.00051	6.63	-0.0007	1145	637 -1281	0	-0.04	0.000017	5985
8	0.00057	6.87	-0.0007	1245	700 -1442	0	0.43	0.000019	6615
9	0.00062	7.07	-0.0008	1353	769 -1620	0	0.43	0.000022	7307
10	0.00069	7.24	-0.0009	1471	846 -1814	0	0.36	0.000024	8066
11	0.00076	7.38	-0.0010	1600	931 -2028	0	0.80	0.000027	8896
12	0.00084	7.49	-0.0012	1739	1025 -2262	0	-0.06	0.000030	9803
13	0.00093	7.58	-0.0013	1890	1130 -2518	0	0.32	0.000033	10792
14	0.00103	7.69	-0.0014	2047	1245 -2790	0	-0.37	0.000036	11833
15	0.00114	8.01	-0.0016	2188	1362 -3048	0	-0.57	0.000041	12754

STRUCTWARE

SHEET C8-17 OF _____JOB TITLE Verification Problem No. 8ORIGINATOR RMDATE 4/7/2004

JOB No. _____

CALCULATION No. _____

REVIEWER _____

DATE _____

16	0.00126	8.52	-0.0019	2309	1479	-3286	0	-0.04	0.000046	13560
17	0.00139	9.23	-0.0021	2409	1593	-3500	0	0.23	0.000052	14233
18	0.00154	9.97	-0.0025	2501	1709	-3709	0	-0.97	0.000059	14862
19	0.00170	10.81	-0.0029	2567	1815	-3879	0	0.88	0.000068	15367
20	0.00188	11.49	-0.0033	2637	1897	-4032	0	0.36	0.000077	15745
21	0.00208	12.11	-0.0038	2709	1963	-4169	0	0.05	0.000087	16056
22	0.00230	12.63	-0.0044	2785	2017	-4301	0	-0.85	0.000099	16328
23	0.00254	13.10	-0.0050	2854	2067	-4420	0	0.21	0.000111	16558
24	0.00281	13.64	-0.0057	2895	2108	-4502	0	-0.64	0.000126	16693
25	0.00311	14.05	-0.0065	2946	2141	-4585	0	0.16	0.000142	16816
26	0.00344	14.39	-0.0074	2999	2170	-4666	0	0.39	0.000159	16922
27	0.00380	14.78	-0.0083	3031	2193	-4722	0	-0.05	0.000179	16985
28	0.00420	15.05	-0.0094	3071	2208	-4777	0	0.04	0.000201	17032
29	0.00464	15.18	-0.0105	3099	2227	-4824	0	0.39	0.000223	17024
30	0.00513	15.19	-0.0116	3105	2259	-4861	0	0.61	0.000247	16956
31	0.00568	15.16	-0.0128	3113	2285	-4897	0	-0.02	0.000273	16887
32	0.00628	15.13	-0.0141	3146	2292	-4936	0	-0.17	0.000301	16860
33	0.00694	15.14	-0.0156	3179	2297	-4975	0	-0.36	0.000333	16850
34	0.00767	15.18	-0.0173	3199	2300	-4997	0	-0.08	0.000369	16832
35	0.00848	15.22	-0.0192	3224	2302	-5023	0	0.56	0.000409	16830
36	0.00937	15.14	-0.0211	3256	2316	-5070	0	0.60	0.000450	16935
37	0.01036	15.00	-0.0231	3293	2340	-5132	0	-0.37	0.000494	17109
38	0.01146	14.85	-0.0253	3345	2369	-5211	0	0.61	0.000543	17359
39	0.01266	14.67	-0.0276	3392	2407	-5297	0	-0.09	0.000595	17633
40	0.01400	14.49	-0.0302	3438	2449	-5386	0	-0.93	0.000652	17912

First Yield of Rebar Information (not Idealized):

Rebar Number 28

Coordinates X and Y (global in.) 0.00, -31.75

Yield strain = 0.00138

Curvature (rad/in)= 0.000035

Moment (ft-k) = 11455

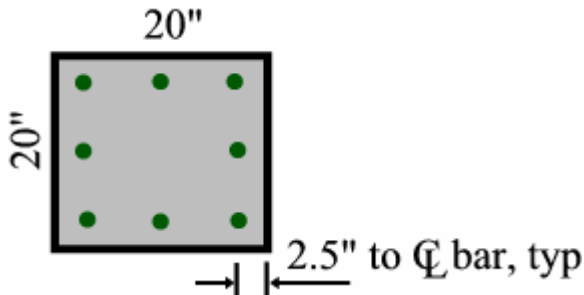
Assume concrete modulus (ksi) = 3561

Cracked Moment of Inertia (ft^4) = 53.109

VERIFICATION PROBLEM NO 9

Check the ACI 318-02 code using the reinforced concrete section from Verification Problem No. 1. The difference from the ACI 318-99 code that is to be verified is the phi factor calculation as a function of the maximum tensile strain in the reinforcement.

File = VER9.OUT



$f'_c = 6000$ psi

$f_y = 60$ ksi

(8) #10 bars

$A_s = 1.27$ in² / bar

LOAD	P (KIPS)	M (K-FT)
1	300	100
2	400	100
3	500	100
4	600	100

"c" values from output file

strain = $-(17.5 - c) \times 0.003 / c$

If strain < -0.005 then phi = 0.90

If strain > -0.002069 then phi = 0.65

Else phi = $0.9 - (-0.005 - \text{strain})(0.9 - 0.65) / (-0.005 + 0.002069)$

LOAD	C (in)	strain	phi
1	6.50	-0.00508	0.900
2	7.73	-0.00379	0.797
3	10.13	-0.00218	0.660
4	11.35	-0.00163	0.650

STRUCTWARE

SHEET C9-2 OF

JOB TITLE Verification Problem No. 9

ORIGINATOR RM

DATE 4/7/2004

JOB No. CALCULATION No.

REVIEWER

DATE

FILE = VER9.OUT

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4/29/02, 1:17 pm

D E S I G N C R I T E R I A

Design Criteria = ACI-318 (2002)
Units = English (inches, pounds)

MATERIAL STRENGTH:

Concrete compressive strength	= 6000
Concrete modulus of elasticity	= 4415201
Reinforcing yield strength	= 60000
Reinforcing modulus of elasticity	= 2.9E+07

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 0.9
Compression and flexure	= 0.65
Shear and torsion	= 0.75

STRESS BLOCK:

Ratio of average concrete strength	= 0.85
Ratio of depth of compression block	= 0.75
Maximum concrete strain	= 0.003

RESISTANCE FACTORS:

Concrete	= 1
Reinforcing	= 1

C O N C R E T E C O N F I G U R A T I O N

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	20	20	1

STRUCTWARE

SHEET C9-3 OF _____

JOB TITLE Verification Problem No. 9 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

3 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
2.5	15	0	3	1.27
10	15	0	2	1.27
17.5	15	0	3	1.27

LOAD CONDITIONS

(Units = K-ft)

4 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	300.0	100.0	0.0	0.0
2	400.0	100.0	0.0	0.0
3	500.0	100.0	0.0	0.0
4	600.0	100.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length = 256

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

STRUCTWARE

SHEET C9-4 OF _____JOB TITLE Verification Problem No. 9 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 4.0000E+02
Ybar = 1.0000E+01
Io = 1.3333E+04 About concrete CG

REINFORCING STEEL:

Area = 1.0160E+01
Ybar = 1.0000E+01
Io = 4.2863E+02 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 4.5657E+02
Ybar = 1.0000E+01
Inertia = 1.5720E+04

INTERACTION DIAGRAM

Moments about centroid of gross concrete section
(Units = K-ft)

C	Mn	Pn	
	0.0	-609.6	Maximum tension
1.00	61.4	-533.1	
2.00	209.0	-310.9	
3.00	347.1	-96.3	
3.78	406.9	1.0	Pure bending
4.00	425.2	29.9	
5.00	493.3	147.8	
6.00	548.0	257.0	
6.50	571.6	334.2	Load condition no 1
7.00	593.0	405.9	
7.73	620.8	502.7	Load condition no 2
8.00	630.2	536.6	
9.00	653.7	644.5	
10.00	672.0	745.6	
10.13	674.1	758.4	Load condition no 3
10.36	677.4	781.0	Balanced strain
11.00	665.1	874.9	

STRUCTWARE

SHEET C9-5 OF _____

JOB TITLE Verification Problem No. 9 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

11.35	658.6	924.1	Load condition no 4
12.00	646.4	1012.1	
13.00	627.2	1140.0	
14.00	606.5	1247.5	
15.00	583.6	1362.2	
16.00	558.1	1472.0	
17.00	529.7	1578.0	
18.00	497.9	1680.7	
19.00	462.6	1780.6	
	0.0	2078.2	Maximum compression

SECTION ANALYSIS

=====

(Units = K-ft)

LOAD CONDITION NO 1

For Axial load	= 300.8
Reduction factor	= 0.900
Moment capacity	= 514.4
Moment demand	= 100.0

LOAD CONDITION NO 2

For Axial load	= 400.6
Reduction factor	= 0.797
Moment capacity	= 494.8
Moment demand	= 100.0

LOAD CONDITION NO 3

For Axial load	= 500.3
Reduction factor	= 0.660
Moment capacity	= 444.7
Moment demand	= 100.0

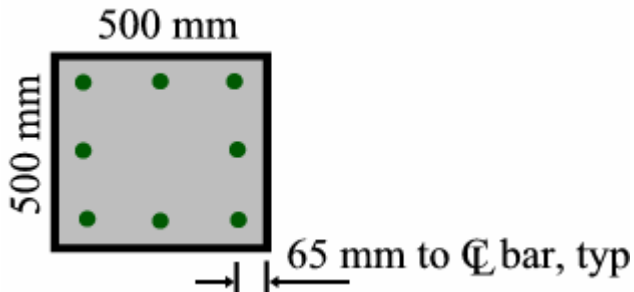
LOAD CONDITION NO 4

For Axial load	= 600.7
Reduction factor	= 0.650
Moment capacity	= 428.1
Moment demand	= 100.0

VERIFICATION PROBLEM NO 10

Check the CAN/CSA-S6 code formulas with a reinforced concrete section similar to the one used for Verification Problem No. 1.

File = VER10.OUT



$f'_c = 40 \text{ MPa}$
 $f_y = 400 \text{ MPa}$

(8) #32 bars
 $A_s = 819 \text{ mm}^2 / \text{bar}$

LOAD	P (kN)	βd	M1ns (kN-m)	M2ns (kN-m)
1	5100	0.87	110	220
2	3900	0.86	90	170

Column L = 6500 mm, $k = 0.86$

STRUCTWARE

SHEET C10-2 OF

JOB TITLE Verification Problem No. 10 ORIGINATOR RM DATE 4/7/2004

JOB No. CALCULATION No. REVIEWER DATE

FILE = VER10.OUT

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D E S I G N C R I T E R I A

=====

Design Criteria = CAN/CSA-S6 (2000)
Units = Metric (millimeters, Newtons)

MATERIAL STRENGTH:

Concrete compressive strength	= 40
Concrete modulus of elasticity	= 28446
Reinforcing yield strength	= 400
Reinforcing modulus of elasticity	= 200000

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 1
Compression and flexure	= 1
Shear and torsion	= 1

STRESS BLOCK:

Ratio of average concrete strength	= 0.79
Ratio of depth of compression block	= 0.87
Maximum concrete strain	= 0.0035

RESISTANCE FACTORS:

Concrete	= 0.75
Reinforcing	= 0.9

C O N C R E T E C O N F I G U R A T I O N

=====

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	500	500	1

STRUCTWARE

SHEET C10-3 OF _____JOB TITLE Verification Problem No. 10 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

3 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
65	370	0	3	819
250	370	0	2	819
435	370	0	3	819

LOAD CONDITIONS

(Units = kN-m)

2 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	5100.0	0.0	0.0	0.0
2	3900.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length	= 6500
Effective length factor	= 0.86

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

SLENDERNESS

(Moments in kN-m)

Moment magnification per design criteria

2 LOAD CONDITIONS:

No	M1ns	M2ns	M1s	M2s
1	110.0	220.0	0.0	0.0
2	90.0	170.0	0.0	0.0

STRUCTWARE

SHEET C10-4 OF _____JOB TITLE Verification Problem No. 10 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

No	BetaD	BetaDs	Tloads
----	-------	--------	--------

1	0.87	0	0
2	0.86	0	0

No	di	dj	ri	rj
----	----	----	----	----

1	0	0	0	0
2	0	0	0	0

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SECTION PROPERTIES

GROSS CONCRETE SECTION:

Area = 2.5000E+05
Ybar = 2.5000E+02
Io = 5.2083E+09 About concrete CG

REINFORCING STEEL:

Area = 6.5520E+03
Ybar = 2.5000E+02
Io = 1.6818E+08 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 2.8951E+05
Ybar = 2.5000E+02
Inertia = 6.2226E+09

INTERACTION DIAGRAM

Moments about centroid of gross concrete section
(Units = kN-m)

C	Mn	Pn	
	0.0	-2358.7	Maximum tension
22.83	56.5	-2123.4	
45.66	137.2	-1732.1	
68.49	335.3	-680.6	
91.32	442.5	-95.2	
95.44	459.5	0.1	Pure bending

STRUCTWARE

SHEET C10-5 OF _____JOB TITLE Verification Problem No. 10 ORIGINATOR RM DATE 4/7/2004

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114.16	525.7	385.1	
136.98	585.4	764.3	
159.80	613.8	999.6	
182.62	637.6	1401.4	
205.44	656.7	1811.0	
228.25	671.1	2185.7	
251.07	680.9	2535.1	
273.92	686.0	2865.8	
287.27	686.8	3052.2	Balanced strain
296.77	671.0	3226.6	
319.62	633.4	3711.5	
328.98	617.9	3900.1	Load condition no 2
342.47	595.5	4163.1	
365.33	556.6	4587.7	
388.18	516.0	4990.1	
394.62	504.1	5100.1	Load condition no 1
411.03	473.1	5373.9	
433.88	427.7	5742.1	
	0.0	6096.3	Maximum compression

S L E N D E R N E S S E F F E C T S

SLENDERNESS PER CAN/CSA-S6 (2000):

LOAD CONDITION 1:

$$P_c = 10686.1$$

$$r = 144.338$$

$$kl/r = 38.7$$

$$kl/r \text{ limit} = 28.0$$

$$\text{Equivalent moment factor, } C_m = 0.800$$

$$\text{Non-sway magnification factor} = 2.200$$

$$\text{Sway magnification factor} = 1.000$$

$$\text{Magnified moment} = 484.0$$

LOAD CONDITION 2:

$$P_c = 10743.5$$

$$r = 144.338$$

$$kl/r = 38.7$$

$$kl/r \text{ limit} = 27.6$$

$$\text{Equivalent moment factor, } C_m = 0.812$$

$$\text{Non-sway magnification factor} = 1.573$$

$$\text{Sway magnification factor} = 1.000$$

$$\text{Magnified moment} = 267.4$$

STRUCTWARE

SHEET C10-6 OF _____

JOB TITLE Verification Problem No. 10 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

S E C T I O N A N A L Y S I S

=====

(Units = kN-m)

LOAD CONDITION NO 1

For Axial load	= 5100.1
Reduction factor	= 1.000
Moment capacity	= 504.1
Magnified moment	= 484.0

LOAD CONDITION NO 2

For Axial load	= 3900.1
Reduction factor	= 1.000
Moment capacity	= 617.9
Magnified moment	= 267.4

- DESIGN CRITERIA

Unit weight $\gamma_c = 24.0 \text{ kN/m}^3$ (2450 kg/m³) from CSA-S6 Table 3.6

$$E = [3000(f'_c)^{1/2} + 6900](\gamma_c/2300)^{1.5} = 28446 \text{ Mpa}$$

$$\alpha_1 = 0.85 - 0.0015f'_c = 0.79$$

$$\beta_1 = 0.97 - 0.0025f'_c = 0.87$$

$$\phi_c = 0.75$$

$$\phi_r = 0.90$$

- INTERACTION DIAGRAM

1. Maximum tension

$$T = 0.9 \times 8 \times 819 \times 400 / 1000 = 2359 \text{ kN}$$

2. Pure bending

$$c = 95.44 \text{ mm (output file)}$$

$$a = 0.87 \times 95.44 = 83 \text{ mm}$$

$$y = 41.5 \text{ mm}$$

$$C_c = 0.75 \times 0.79 \times 40 \times 500 \times 83 / 1000 = 984 \text{ kN}$$

$$\epsilon_1 = (95 - 65)(0.0035/95) = 0.001116$$

$$\sigma_1 = 0.001116 \times 200000 = 223 \text{ Mpa} < 0.9 \times 400 = 360 \text{ Mpa}$$

$$C_1 = 3 \times 819 (223 - 0.75 \times 0.79 \times 40) / 1000 = 490 \text{ kN}$$

$$y = 65 \text{ mm}$$

$$\epsilon_2 = (95 - 250)(0.0035/95) = -0.005668$$

$$\sigma_2 = -0.005668 \times 200000 = -1134 \text{ Mpa} < -360 \text{ MPa}$$

$$T_2 = -2 \times 819 \times 360 = -590 \text{ kN}$$

$$y = 250 \text{ mm}$$

$$T_3 = -3 \times 819 \times 360 = -885 \text{ kN}$$

$$y = 435 \text{ mm}$$

$$P_n = -1 \text{ kN}$$

$$M_n = 984 \times .0415 + 490 \times .065 - 590 \times .25 - 885 \times .435 = 459 \text{ kN-m}$$

3. Balanced strain

$$c = 287 \text{ mm (output file)}$$

$$a = 0.87 \times 287 = 250 \text{ mm}$$

$$y = 125 \text{ mm}$$

$$C_c = 0.75 \times 0.79 \times 40 \times 500 \times 250 / 1000 = 2963 \text{ kN}$$

$$\varepsilon_1 = (287 - 65)(0.0035/287) = 0.002707$$

$$\sigma_1 = 0.002707 \times 200000 = 541 \text{ Mpa} > 0.9 \times 400 = 360 \text{ Mpa}$$

$$C_1 = 3 \times 819 (360 - 0.75 \times 0.79 \times 40)/1000 = 826 \text{ kN}$$

$$y = 65 \text{ mm}$$

$$\varepsilon_2 = (287 - 250)(0.0035/287) = 0.000451$$

$$\sigma_2 = 0.000451 \times 200000 = 90 \text{ Mpa}$$

$$C_2 = 2 \times 819 \times 90 = 147 \text{ kN}$$

$$y = 250 \text{ mm}$$

$$\varepsilon_3 = (287 - 435)(0.0035/287) = -0.00180$$

$$\sigma_3 = -0.00180 \times 200000 = -360 \text{ Mpa}$$

$$T_3 = -3 \times 819 \times 360 = -885 \text{ kN}$$

$$y = 435 \text{ mm}$$

$$P_n = 3051 \text{ kN}$$

$$ecc = 0.25 - (2963 \times 125 + 826 \times 65 + 147 \times 25 - 885 \times 435) / 3051 = 0.225 \text{ m}$$

$$M_n = 3052 \times 0.225 = 687 \text{ kN-m}$$

4. Maximum compression

$$P_n = .75[.75 \times .79 \times 40(500)^2 + (.9 \times 400 - .75 \times .79 \times 40)(8 \times 819)] = 6096 \text{ kN}$$

- SLENDERNESS EFFECTS

$$r = (5.2083 \times 10^9 / 2.5 \times 10^5)^{1/2} = 144.3 \text{ mm}$$

$$kl/r = 0.86 \times 6500 / 144.3 = 38.7$$

Load case 1:

$$kl/r \text{ limit} = 34 - 12(110/220) = 28.0$$

$$C_m = 0.6 + 0.4 \times 110/220 = 0.8$$

$$\beta_d = 0.87$$

STRUCTWARE

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$$EI = (0.2E_cI_c + E_sI_s) / (1 + \beta_d) = 3.383 \times 10^{13}$$

$$P_c = \pi^2 EI / (kl)^2 = 10685 \text{ kN}$$

$$\delta = 0.8 / [1 - 5100 / (.75 \times 10685)] = 2.20$$

$$M = 2.20 \times 220 = 484 \text{ kN-m}$$

Load case 2:

$$kl/r \text{ limit} = 34 - 12(90/170) = 27.6$$

$$C_m = 0.6 + 0.4 \times 90/170 = 0.812$$

$$\beta_d = 0.86$$

$$EI = (0.2E_cI_c + E_sI_s) / (1 + \beta_d) = 3.4 \times 10^{13}$$

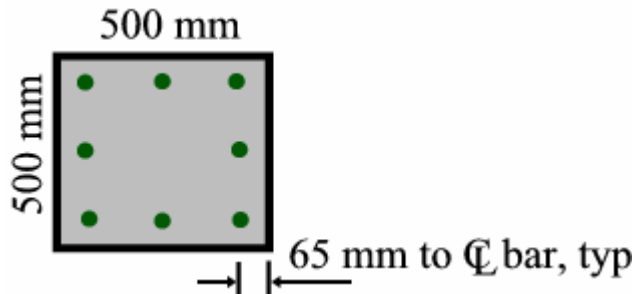
$$P_c = \pi^2 EI / (kl)^2 = 10739 \text{ kN}$$

$$\delta = 0.812 / [1 - 3900 / (.75 \times 10739)] = 1.574$$

$$M = 1.574 \times 170 = 268 \text{ kN-m}$$

VERIFICATION PROBLEM NO 11

Check the CSA-A23.3 code formulas with a reinforced concrete section similar to the one used for Verification Problem No. 1.



$f'_c = 40 \text{ MPa}$

$f_y = 400 \text{ MPa}$

(8) #32 bars

$A_s = 819 \text{ mm}^2 / \text{bar}$

LOAD	P (kN)	βd	M1ns (kN-m)	M2ns (kN-m)
1	5100	0.87	110	220
2	3900	0.86	90	170

Column L = 6500 mm, $k = 0.86$

STRUCTWARE

SHEET C11-2 OF

JOB TITLE Verification Problem No. 11

ORIGINATOR RM

DATE 4/7/2004

JOB No. CALCULATION No.

REVIEWER

DATE

CSA-A23.3 Verification Problem

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(Version 1.4) 9/17/05, 9:25 am

Input file = VER11.IN
Output file = VER11.out

D E S I G N C R I T E R I A

Design Criteria = CSA A23.3 (2004)
Units = Metric (millimeters, Newtons)

MATERIAL STRENGTH:

Concrete compressive strength	= 40
Concrete modulus of elasticity	= 28460
Reinforcing yield strength	= 400
Reinforcing modulus of elasticity	= 200000

STRENGTH REDUCTION FACTORS:

Tension and flexure	= 1
Compression and flexure	= 1
Shear and torsion	= 1

STRESS BLOCK:

Ratio of average concrete strength	= 0.79
Ratio of depth of compression block	= 0.87
Maximum concrete strain	= 0.0035

RESISTANCE FACTORS:

Concrete	= 0.65
Reinforcing	= 0.85

C O N C R E T E C O N F I G U R A T I O N

1 RECTANGULAR SECTIONS:

Ytop	Depth	Width	Add
0	500	500	1

STRUCTWARE

SHEET C11-3 OF _____JOB TITLE Verification Problem No. 11 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

REINFORCING CONFIGURATION

3 REINFORCING LINES:

Ybeg	Length	Angle	Nbar	Abar
65	370	0	3	819
250	370	0	2	819
435	370	0	3	819

LOAD CONDITIONS

(Units = kN-m)

2 LOAD CONDITIONS:

No	Axial	Moment	Shear	Torsion
1	5100.0	0.0	0.0	0.0
2	3900.0	0.0	0.0	0.0

MEMBER PROPERTIES

MEMBER PROPERTIES:

Member length	= 6500
Effective length factor	= 0.86

BOUNDARY CONDITIONS:

Condition	End i	End j
Shear restraint	1	1
Moment restraint	0	0

SLENDERNESS

(Moments in kN-m)

Moment magnification per design criteria

2 LOAD CONDITIONS:

No	M1ns	M2ns	M1s	M2s
1	110.0	220.0	0.0	0.0
2	90.0	170.0	0.0	0.0

STRUCTWARE

SHEET C11-4 OF _____JOB TITLE Verification Problem No. 11 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

No	BetaD	BetaDs	Tloads
----	-------	--------	--------

1	0.87	0	0
2	0.86	0	0

No	di	dj	ri	rj
----	----	----	----	----

1	0	0	0	0
2	0	0	0	0

```
* * * * *
*
*       P R O G R A M   C O N S E C
*
*       O U T P U T   D A T A
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```

SECTION PROPERTIES

=====

GROSS CONCRETE SECTION:

Area = 2.5000E+05
Ybar = 2.5000E+02
Io = 5.2083E+09 About concrete CG

REINFORCING STEEL:

Area = 6.5520E+03
Ybar = 2.5000E+02
Io = 1.6818E+08 About reinf CG

TRANSFORMED CONCRETE SECTION:

Area = 2.8949E+05
Ybar = 2.5000E+02
Inertia = 6.2220E+09

INTERACTION DIAGRAM

=====

Moments about centroid of gross concrete section
(Units = kN-m)

C	Mn	Pn	
	0.0	-2227.7	Maximum tension
24.00	51.4	-2013.2	
48.00	140.1	-1572.6	
72.00	326.2	-581.8	
96.00	426.6	-29.6	
98.00	430.9	12.0	Pure bending
120.00	503.1	417.7	

STRUCTWARE

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144.00	540.8	679.2	
168.00	565.3	893.7	
192.00	585.4	1318.7	
216.00	600.9	1699.0	
240.00	612.0	2046.1	
264.00	618.6	2369.2	
288.00	620.7	2640.4	
293.00	620.2	2703.9	Balanced strain
312.00	589.2	3088.8	
336.00	550.7	3540.1	
357.00	516.8	3908.9	Load condition no 2
360.00	511.9	3959.9	
384.00	472.1	4354.0	
408.00	430.6	4726.9	
432.00	387.0	5082.3	
434.00	383.3	5111.2	Load condition no 1
456.00	341.0	5422.8	
480.00	292.1	5750.7	
	0.0	5782.5	Maximum compression

S L E N D E R N E S S E F F E C T S

SLENDERNESS PER CSA A23.3 (2004):

LOAD CONDITION 1:

$$P_c = 10688.5$$

$$r = 144.338$$

$$kl/r = 38.7$$

$$kl/r \text{ limit} = 28.0$$

$$\text{Equivalent moment factor, } C_m = 0.800$$

$$\text{Non-sway magnification factor} = 2.199$$

$$\text{Sway magnification factor} = 1.000$$

$$\text{Magnified moment} = 483.8$$

LOAD CONDITION 2:

$$P_c = 10746.0$$

$$r = 144.338$$

$$kl/r = 38.7$$

$$kl/r \text{ limit} = 31.6$$

$$\text{Equivalent moment factor, } C_m = 0.812$$

$$\text{Non-sway magnification factor} = 1.573$$

$$\text{Sway magnification factor} = 1.000$$

$$\text{Magnified moment} = 267.4$$

STRUCTWARE

SHEET C11-6 OF _____

JOB TITLE Verification Problem No. 11 ORIGINATOR RM DATE 4/7/2004

JOB No. _____ CALCULATION No. _____ REVIEWER _____ DATE _____

S E C T I O N A N A L Y S I S

=====

(Units = kN-m)

LOAD CONDITION NO 1

For Axial load = 5111.2
Reduction factor = 1.000
Moment capacity = 383.3
Magnified moment = 483.8
*** Moment capacity is exceeded

LOAD CONDITION NO 2

For Axial load = 3908.9
Reduction factor = 1.000
Moment capacity = 516.8
Magnified moment = 267.4

- DESIGN CRITERIA

$$E = 4500(f'_c)^{1/2} = 28460 \text{ Mpa}$$

$$\alpha_1 = 0.85 - 0.0015f'_c = 0.79$$

$$\beta_1 = 0.97 - 0.0025f'_c = 0.87$$

$$\phi_c = 0.65$$

$$\phi_r = 0.85$$

- INTERACTION DIAGRAM

5. Maximum tension

$$T = 0.85 \times 8 \times 819 \times 400 / 1000 = 2228 \text{ kN}$$

6. Pure bending

$$c = 98 \text{ mm (output file)}$$

$$a = 0.87 \times 98 = 85 \text{ mm}$$

$$y = 42.6 \text{ mm}$$

$$C_c = 0.65 \times 0.79 \times 40 \times 500 \times 85 / 1000 = 876 \text{ kN}$$

$$\epsilon_1 = (98 - 65)(0.0035/98) = 0.001179$$

$$\sigma_1 = 0.001179 \times 200000 = 236 \text{ Mpa} < 0.85 \times 400 = 340 \text{ Mpa}$$

$$C_1 = 3 \times 819 (236 - 0.65 \times 0.79 \times 40) / 1000 = 529 \text{ kN}$$

$$y = 65 \text{ mm}$$

$$\epsilon_2 = (98 - 250)(0.0035/98) = -0.005429$$

$$\sigma_2 = -0.005429 \times 200000 = -1086 \text{ Mpa} < -340 \text{ MPa}$$

$$T_2 = -2 \times 819 \times 340 = -557 \text{ kN}$$

$$y = 250 \text{ mm}$$

$$T_3 = -3 \times 819 \times 340 = -835 \text{ kN}$$

$$y = 435 \text{ mm}$$

$$P_n = 876 - 529 - 557 - 835 = 13 \text{ kN}$$

$$M_n = 876 \times .0426 + 529 \times .065 - 557 \times .25 - 835 \times .435 = 431 \text{ kN-m}$$

7. Balanced strain

$$c = 293 \text{ mm (output file)}$$

$$a = 0.87 \times 293 = 255 \text{ mm}$$

$$y = 127.5 \text{ mm}$$

$$C_c = 0.65 \times 0.79 \times 40 \times 500 \times 255 / 1000 = 2619 \text{ kN}$$

$$\epsilon_1 = (293 - 65)(0.0035/293) = 0.002724$$

$$\sigma_1 = 0.002724 \times 200000 = 545 \text{ Mpa} > 0.85 \times 400 = 340 \text{ Mpa}$$

$$C_1 = 3 \times 819 (340 - 0.65 \times 0.79 \times 40) / 1000 = 785 \text{ kN}$$

$$y = 65 \text{ mm}$$

$$\epsilon_2 = (293 - 250)(0.0035/293) = 0.000514$$

$$\sigma_2 = 0.000514 \times 200000 = 103 \text{ Mpa}$$

$$C_2 = 2 \times 819 \times 103 = 168 \text{ kN}$$

$$y = 250 \text{ mm}$$

$$\epsilon_3 = (293 - 435)(0.0035/293) = -0.001696$$

$$\sigma_3 = -0.001696 \times 200000 = -339 \text{ Mpa}$$

$$T_3 = -3 \times 819 \times 339 = -834 \text{ kN}$$

$$y = 435 \text{ mm}$$

$$P_n = 2619 + 785 + 168 - 834 = 2738 \text{ kN}$$

$$ecc = 0.25 - (2619 \times 127 + 785 \times 65 + 168 \times 25 - 834 \times 435) / 2738 = 0.227 \text{ m}$$

$$M_n = 2738 \times 0.227 = 622 \text{ kN-m}$$

8. Maximum compression

$$P_n = .80[.65 \times .79 \times 40(500)^2 + (.85 \times 400 - .65 \times .79 \times 40)(8 \times 819)] = 5782 \text{ kN}$$

• SLENDERNESS EFFECTS

$$r = (5.2083 \times 10^9 / 2.5 \times 10^5)^{1/2} = 144.3 \text{ mm}$$

$$kl/r = 0.86 \times 6500 / 144.3 = 38.7$$

Load case 1:

$$kl/r \text{ limit} = 25 - 10(110/220) / [5100000 / (40 \times 2.5 \times 10^5)]^{1/2} = 28.0$$

$$C_m = 0.6 + 0.4 \times 110/220 = 0.8$$

$$\beta_d = 0.87$$

STRUCTWARE

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$$EI = (0.2E_cI_c + E_sI_s) / (1 + \beta_d) = 3.384 \times 10^{13}$$

$$P_c = \pi^2 EI / (kl)^2 = 10688 \text{ kN}$$

$$\delta = 0.8 / [1 - 5100 / (.75 \times 10688)] = 2.20$$

$$M = 2.20 \times 220 = 484 \text{ kN-m}$$

Load case 2:

$$kl/r \text{ limit} = 25 - 10(90/170) / [3900000 / (40 \times 2.5 \times 10^5)]^{1/2} = 31.6$$

$$C_m = 0.6 + 0.4 \times 90/170 = 0.812$$

$$\beta_d = 0.86$$

$$EI = (0.2E_cI_c + E_sI_s) / (1 + \beta_d) = 3.4 \times 10^{13}$$

$$P_c = \pi^2 EI / (kl)^2 = 10746 \text{ kN}$$

$$\delta = 0.812 / [1 - 3900 / (.75 \times 10746)] = 1.573$$

$$M = 1.573 \times 170 = 267 \text{ kN-m}$$